DEVELOPING NATIVE GRASS SEED INDUSTRIES FOR REVEGETATION IN AUSTRALIA AND THE WESTERN UNITED STATES: A CONTRAST IN PRODUCTION AND ADOPTION

C.M. Waters[1] and N.L. Shaw[2]

[1]NSW Agriculture, Agricultural Research Centre, Trangie, New South Wales, Australia 2823.
E-mail: cathy.waters@agric.nsw.gov.au
[2]USDA Forest Service, Rocky Mountain Research Station, 316 E. Myrtle, Boise, Idaho 83702, U.S.A.
E-mail: nshaw@fs.fed.us

ABSTRACT

Globally, an increased desire to restore, rehabilitate or revegetate with native plants represents a shift toward more ecologically focused restoration goals. In the Australian rangelands, an increasing need to address revegetation is not being matched by an availability of seed material. This contrasts with the United States where a well-structured native seed industry, capable of large-scale revegetation is developing. Most native revegetation programs in the United States are undertaken on Federal or State lands, or on private lands where use of native material is federally mandated, leading to a 'top-down' approach to the development and use of seed material. In Australia, most revegetation is being undertaken on privately owned land, primarily through community Landcare groups, resulting in broad community adoption of a conservation ethic. The Australian 'bottom-up' approach has encouraged landholders to establish their own seed orchard areas or community seed banks and contributes to a developing "cottage" native seed industry. However, most revegetation programs are of small scale and of short duration, thus prohibiting the further development of a commercial native seed industry. This paper traces the evolution of the Australian and American native grass seed industries, and evaluates their relative merits and shortcomings. We compare the different roles of the two governments in shaping and facilitating development of these industries.

1. INTRODUCTION

Desertification is a large-scale problem throughout the semi-arid and arid rangelands of the world (Mouat & Hutchinson 1995). Some 42 % or 5 million km^2 of Australia's rangelands are affected by some form of degradation; the most common being a loss of perennial grasses (Ludwig & Tongway 1995). In the United States, about 76 % of dry-land areas are degraded to some degree (Mouat & Hutchinson 1995). On both continents losses in the perennial component have occurred over a short time frame, usually within one or two generations as a result of grazing management practises unsuited to long-term sustainable land-use (Harrington *et al.* 1984) and unprofitable dryland farming enterprises. Loss of perennial grasses in the marginal croplands of the United States has resulted in massive soil erosion. In Australia, a loss of native perennials to annual crops and pastures has caused dryland salinity and represents the largest natural resource management issue in that country. The strategy to address these degradation issues has traditionally been to reseed these areas with introduced perennial species, although some natives have been in use for many years in the United States. More recently, in both countries, the trend has been towards the use of native species where possible, with a clear recognition of their intrinsic adaptive and ecological value.

Native grasses, whether as an understorey or grassland community, cover vast landscapes in both countries. Until recently, however, they received limited use in revegetation activities due to the perception that introduced species are more readily established, more productive, and more persistent. In the United States, seed of a number of regionally adapted cultivars of widespread species of native grasses that are easily grown in cultivation are now available in considerable quantity. Seed of other, widespread species that are less easily cultivated and more geographically restricted, can rarely be purchased. Past large-scale revegetation exercises in Australia have focused primarily on planting trees and shrubs. Native grasses are generally sown on small areas using one or two easily sourced species. If both countries aim to move toward large-scale restoration of native plant communities, insuring the availability of adequate supplies of locally adapted seed is an issue of great strategic importance. Whether for perennial native grasslands or understorey replenishment, native seed is needed in vast quantities to address major environmental problems such as salinity, erosion, weed and wildfire control, wildlife habitat improvement, and loss of biodiversity. However, these areas are requiring revegetation at a scale that native grass seed industries in both countries are failing to meet. Despite this increasing demand for seed, the native grass seed market experiences large fluctuations, interfering

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with market stability. These fluctuations in demand are causing those involved with this industry to examine possible avenues for improving its structure (Jones 1997).

Since the 1970's there has been a growing interest in environmental issues in both Australia and the United States. In particular, the application of the principles of ecologically sustainable development requires the consideration of conservation of biological diversity and ecological integrity. This is resulting in an increased desire from community and government groups to revegetate native plant communities rather than sowing a single broadly adapted species. Thus the demand is not only for large quantities of seed but also for a broad range of species and locally adapted material of each species. Globally, these are the issues that will likely provide the continued long-term drivers for development of native seed industries.

2. AUSTRALIA

2.1 Historic drivers

In Australia the pastoral industry of the late 1890s was completely based on native pastures, primarily grasses. First settlement brought with it a suppression of fire that had been important in promoting habitat diversity and maintaining a balance between populations of unpalatable endemic shrubs and herbage layers (Hodgkinson *et al.* 1984). Added to this, grazing pressure from domestic and feral herbivores increased to such an extent that it had only taken a few generations for these native forage resources to decline markedly (Noble 1997). Annual native grasses, unpalatable perennial grasses, and shrubs replaced the palatable perennial grasses and carrying capacity of the land declined (Barr & Cary 1992). In eastern Australia, the devastating effects of these declines were exaggerated by an extensive drought between 1890 and 1902. These effects were so great that almost one third of the state of New South Wales was declared unprofitable as a result of widespread destitution among landholders, resulting in a public enquiry (Royal Commission 1901).

At this time State Departments of Agriculture began a period of "improved" pasture research that lasted for almost 70 years. A 'replacement philosophy' dominated, where introduced species were sown to replace the 'inferior' native pastures (Donald 1970). During this period there was almost a complete lack of native grass research (Whalley 2000). The innate infertility of Australian soils was addressed by use of fertilizers to accommodate growth requirements of introduced pasture species. Seeding of these species peaked between 1950 and 1965, a time of high wool prices and widespread use of superphosphate. The tremendous productivity gains in the temperate areas of eastern Australia at this time were part of the reason Australia became known as "the lucky country" (Barr & Cary 1992). However, the same levels of productivity were not experienced in the arid and semi-arid rangelands. Despite the evaluation of over 500 introduced accessions in the state of Queensland alone, introduced grasses, with the exception of *Cenchrus* spp. (e.g. buffel grass) failed to persist in these areas of low and highly variable rainfall (Johnston 1990).

2.2 Agronomically superior native grass cultivars

By the 1980's the usefulness of introduced species as pastures was being challenged and the adaptive advantages of native species being recognised in the arid (Reu 1995) and semi-arid (Leigh 1990, Wilson 1996) Australian rangelands. In these lower rainfall areas (<500 mm annually) introduced species failed to persist and the weediness of some introduced species such as *Cenchrus ciliaris* (buffel grass) grew (Griffin 1993). In temperate rangelands areas, prolonged dry periods and loss of summer active perennials also focused attention on development of native grass cultivars (Lodge 1996). More recently, low summer water use of introduced grasses such as *Phalaris aquatica* (canary grass) and *Dactylis glomerata* (cocksfoot) was identified as a major contributor to water table recharge and increased dryland salinity, now one of the biggest environmental problems facing Australia. For example, currently some 5.7 million hectares are affected with a projected increase to 17 million ha before 2050 (Coram *et al.* 2002). The potential for native grasses to control recharge has since been well documented (Anon 1992, Johnston *et al.* 1999) and offers an opportunity for large-scale expansion native plant revegetation activities.

A number of Australian research programs commencing in the late 1980's attempted to make seed of native grasses commercially available through domestication programs (Lodge 1996). Thus the development of cultivars of Australia native grasses is relatively recent. These projects, some of which are continuing today, mark the beginning of the Australian-native seed industry. Enactment of the Plant Varieties Rights legislation in 1987 and later Plant Breeders Rights (PBR) provided a mechanism for the licensing of varieties and guaranteed protection of ownership of new varieties. This undoubtedly afforded the economic stimulus upon which these programs commenced. Currently nine cultivars have been released under these schemes and a further twelve advanced selections released publicly, without the commercial guarantees of PBR (Waters *et al.* 2000). Collectively, these represent some 12 species, a small proportion of the 1000 Australian native grass species potentially available. Despite over a decade of research, none of these species is available in sufficient quantities to allow broad-scale revegetation to occur. The price of these cultivars

and advanced selections remains high, around $US100 per kg, allowing only the mining and amenity industries to source this material (Mortlock 1999).

Unlike the Federally funded plant selection and breeding programs being undertaken in the United States, the Australian programs were largely funded by levies on the wool, grain or beef industries. Because of this, revegetation goals of these programs were production focused, leading to the selection of cultivars with superior production characteristics (seed and biomass) in addition to a broad adaptive range. Despite this emphasis, practical field scale seed production remains a major obstacle to advancement of selected cultivars and accessions. Traditional pasture seed producers manage for one high-yield seed harvest, however native grasses innately have low seed yields. These production expectations have led to many members of the traditional seed industry viewing native grasses as a non-commercial proposition.

The very characteristics that are prohibiting high seed yield also assist native grasses in adapting to the Australian environment. For example, characteristically native grasses possess differential flowering and ripening with many species exhibiting indeterminate flowering behaviour. Here, seed is produced progressively along inflorescences, and inflorescences are produced progressively on the plant throughout the growing period. In addition, low seed retention is common amongst species, allowing only small proportions of mature seed to be harvested at any one time. Whilst harvesting methods such as the North American brush harvester (Beisel 1983) provide means of non-destructive harvest, efficiencies of this and other techniques are unknown (Waters *et al.* 2000). The chaffy, fluffy nature of Australian grass seed is also problematic for handling and seed sowing. Australian grasses tend to have hairy structures, a callus or long awns that may aid establishment; their removal may result in increased mortality of seedlings.

2.3 The role of voluntary conservation groups – Landcare

The Landcare concept was conceived in 1986, from an alliance between the National Farmers Federation and the Australian Conservation Foundation. Whilst traditionally these groups tended to be in direct opposition, they found common ground in recognition of the increasing land degradation in Australia and an associated loss in primary production. The majority of Landcare groups are rural based and address a range of land conservation issues from erosion and soil acidity to tree decline, water quality, and wildlife conservation. These groups share a common vision. Firstly, they recognise the urgency of addressing environmental land management issues. Secondly, they understand the individual cannot accomplish this alone, solutions require a co-operative effort at a catchment or district level (Campbell 1994). This awareness was reinforced nationally by the development of farm and catchment planning processes in the mid 1980's (Matherson 1996). Over its first decade, Landcare was supported with a $USD170 million federal investment through the Natural Heritage Trust Fund (NHT 2002). Apart from support to rehabilitate land through Landcare, a further $USD165 million has been provided to support Bushcare, the largest Australian native vegetation restoration program. In both these programs, each federal dollar requires an equivalent contribution from the community. There are now more then 4000 Landcare groups across Australia. There has been a continued commitment from the Australian Federal government of $2.7 billion to support these initiatives through extension of the Natural Heritage Trust Fund (NHT 2002).

Whilst scientists were struggling with issues of commercial seed production of a limited range of cultivars, private landholders (farmers and graziers) working through the Landcare movement created an increasing demand for seed of a wide range of native species. Large quantities of low cost seed of many species, particularly of local provenance, were needed for large-scale seeding activities, and the commercial seed industry was failing to satisfy this market (Mortlock 1999).

Some Landcare groups are currently attempting to address this market failure. For example the STIPA Native Grasses Association is a non-government organisation with its roots in Landcare that is based in eastern Australia (STIPA 2002). It is involved with the practical aspects of using and managing native grasslands and their use in farming systems. This group has set themselves up to act as a seed brokerage service to place members in contact with suppliers of wildland-harvested seed. Many members collect significant quantities of native grass seed for use on their own land. Another non-government, non-profit organisation is Greening Australia. This organisation operates in each State and Territory and focuses on assisting and encouraging the community in vegetation-related projects. It provides community seed banks to assist in provision of local indigenous seed at reduced or zero cost. There are some 50 community-based seed collection and storage operations in Australia (Mortlock 1999). Whilst not all supply native grass seed, approximately 42 % of this seed is supplied at no cost (Mortlock 1999). As an alternative method of seed supply, remnant vegetation areas are being managed for seed production, and effectively operate as a seed orchard (Smith 2001, Warn 2002). These seed orchard areas are attempting to enable a supply of seed to meet local revegetation needs.

The quantity and quality of Australian native grass seed is highly variable (Waters & Monsen 1999). As most the Australian native grass seed industry relies on collection of seed from wild stands, seed supply and quality is irregular, being dependent on local seasonal conditions. Australian native grasses have a reputation of being difficult to establish, with many more failures than successes. This lack of success is likely related, at least in part, to the unknown physical quality of seed lots as little seed sold is tested for germination or viability (Mortlock 1999). This notable lack of establishment successes has been an important reason why the industry has been slow to develop. There is also no official system of native seed certification or labelling in Australia, however useful philosophical and practical guidelines are available (Florabank 2002, Seed Industry Association of Australia 2002), resulting in the geographic origin (or provenance) of the seed lot being unknown.

3. UNITED STATES

3.1 Historic drivers

Whilst the Australian rangelands provided the focus for native grass research, in the United States the push for the use of native plant material originated, to some extent, from the cropping areas. Expansion of cropping into increasingly marginal areas of the Great Plains, and a series of severe droughts, resulted in widespread erosion during the Dust Bowl Era of the 1930's (Weaver 1954). Millions of hectares of cultivated land unsuitable for cropping were left bare and susceptible to erosion, major flood events, and watershed deterioration (Monsen & Shaw 2001). The Federally funded United States Department of Agriculture (USDA) Soil Conservation Service (now the Natural Resources Conservation Service or NRCS) was formed to address these problems. The NRCS established a nationwide system of Plant Materials Centres to develop plant material for revegetation and restoration of private and public lands. Specialists at field offices assist landowners and managers with land management and revegetation plans. Initially the Plant Material Centres focused on introduced species such as intermediate wheatgrass (*Elytrigia intermedia*) and wheatgrasses (*Agropyron* spp). Although some plant materials were available earlier, releases by the Centres were used widely for reseeding extensive rangeland areas of the Intermountain West that were seriously degraded by early livestock grazing practices and dryland farming attempts (Monsen & Shaw 2001). However, within 40 years the focus was beginning to shift to native species, encouraged by environmental concerns for conservation of biodiversity and wildlife habitat improvement (Smith & Whalley 2002). The Plant Material Centres continue today, and have been responsible for the testing and release of more than 325 native cultivars, including 176 native grass releases (Alderson & Sharp 1994, Englert *et al.* 2002), likely more native grass cultivars than have been developed anywhere else in the world (Smith & Whalley 2002). In addition, universities and other State and Federal agencies have developed plant materials programs and added considerably to this effort (Monsen & Shaw 2001).

3.2 Post-fire rehabilitation of federal land

As in Australia, early settlement in The United States eventually resulted in a suppression of fire. Over the longer term, however, some rangelands of the United States have experienced an increase in fire frequency. Inappropriate grazing management favoured the spread of highly flammable species such as cheatgrass (*Bromus tectorum*) and other annual weeds into degraded rangelands (Monsen & Shaw 2001). By 1992 almost 1.3 million hectares of federal lands were dominated by annual grasses and a further 30.8 million hectares of public rangelands were weed infested or susceptible to invasion (Pellant & Hall 1994). During the 1990s an average of 654,113 hectares of USDI Bureau of Land Management (BLM) land burned each year, however this increased dramatically during 1999 and 2000 when millions of hectares of public lands burned (USDI/USDA 2002). Post-fire revegetation with perennial species aims to reduce the spread of annual weeds. Federal mandates direct that native materials be used where possible to restore these areas (Clinton 1999; Monsen & Shaw 2001). This has created an enormous demand for native grass seed and provided a major stimulus to development of the native grass seed industry. Severe fire seasons experienced in the United States over the past few years, however, highlight ongoing supply problems. From 1996 to1998 the proportion of native seed marketed remained relatively stable with less than 450,000 kg of seed sold annually (USDA 2002). This changed in 1999 as extensive wildfires created a demand for 2.7 million kg of seed for fire rehabilitation. This demand also tripled seed prices relative to the previous years. In 2001, BLM grass see purchases declined to 770,000 kg (Monsen & Shaw 2001). These fluctuations in seed demand and prices reflect the short-term nature of seed supplies, at least for a single agency (BLM). Seed warehousing by the BLM in Idaho and the Utah Division of Wildlife Resources have provided some measure of stability to these market fluctuations (Monsen & Shaw 2001). However, warehousing requires a high capital input and, for the commercial seed industry, at least, it may not be an economical option for stocking local accessions (Bermant & Spackeen 1997).

3.3 Conservation Reserve Program

From about 1970 increased commodity prices prompted primary producers to expand cropping areas. This continued until the early 1980s when overproduction and low prices had a catastrophic effect on farm incomes (USDA 2002). In 1985 the United States Food Security Act mandated retirement of approximately 16.2 to18.2 million hectares of marginal croplands to reduce surplus grain supplies and soil erosion. Under the Conservation Reserve Program (CRP), some croplands became eligible nationally for reseeding to perennial species to provide permanent cover. The initial

program cost some $1.8 billion US annually and ended in 1995. During that time the CRP program created a huge and immediate demand for native seed of a limited number of grass species as farmers entered into contracts guaranteeing them an agreed annual income for 10 years. While initial CRP objectives were to reduce soil erosion on highly erodible cropland, the focus has recently shifted to retirement of only environmentally sensitive lands (USDA 2002). The program has been extended, with new direction emphasising environmental benefits. Less than 81,000 ha were signed on to the program in 1997 (USDA 2002). From 1987 to 2001, about 4.4 million hectares of CRP lands in the 11 western states were planted with introduced grasses to improve soil stability, while another 6.9 million hectares were planted with regionally native grasses (Monsen & Shaw 2001). Wildlife habitat improvement was undertaken on about 250,000 hectares. Inadequate supplies of certified seed, required for the program, restricted the use of natives.

The CRP provided a major stimulus to the native grass seed market. However, because of wide fluctuations in seed demands for both the CRP program and post-fire re-seeding on public lands, seed supply remained a major problem. Inadequate supplies of requested species resulted in price escalations and alternatives to the desired native species mix being used (Monsen & Shaw 2001). The program did, nonetheless, encourage development of additional native plant materials, particularly native grasses.

3.4 Locally adapted ecotypes

The growing emphasis on non-commodity values of rangelands in the United States has been a major factor driving the move to greater use of locally adapted selections of native species to restore depleted native communities and reduce the use of introduced forage species. A dramatic fluctuation in wildlife herd numbers between 1940 and 1959 prompted large-scale habitat restoration efforts to stabilize herd size. This work required a broad range of species, including grasses, broadleaf herbs, and shrubs. Although introduced grasses were widely used initially, research with native species indicated that at least some species could be used successfully for revegetation. This research revealed the ecotypic nature of many native species and led to investigations of native plant genetics, ecology, and population biology that continue today (Monsen & Shaw 2001; Roundy *et al.* 1997). Government mandates and programs to revegetate wildland disturbances using adapted native species to the extent possible ensure that research and application emphases on the maintenance of genetic variation within seed sources and use of locally adapted ecotypes will expand in the future (Jones 1990, 1998; Monsen & Shaw 2001; USDA/USDA 2002).

3.5 Seed certification

Use of locally adapted material and maintenance of genetic diversity within populations requires verification of seed origin and regulation of the number of generations grown in commercial seed fields. In the United States, the formal cultivar release program accommodates traditional "bred" plant material and is similar to the Plant Breeders' Rights scheme used to release native cultivars in Australia (Young *et al.* 1995). To accommodate certification and release of site-specific materials the Utah Crop Improvement Association developed Pre-variety Germplasm Standards for native, non-genetically manipulated material that was accepted by the Association of Official Seed Certifying Agencies (AOSCA 1997). This program facilitates release of native germplasm that are needed for immediate use when commercial supplies are limited or unavailable or if the commercial potential is low. Categories in this track include (1) Source Identified (identified by location); (2) Selected (shows superior desired characteristics when grown with other collections in common gardens); and (3) Tested (progeny testing indicates stable heredity). Cultivars developed through this track are released through the traditional formal release program. Although the Pre-varietal Germplasm Release Program was only introduced in 1993 it is gaining widespread use. More than half the USDA NRCS cultivars developed between 1990 and 1999 were released through this program (Monsen & Shaw 2001).

4. DISCUSSION

Most revegetation efforts in the United States have been conducted on public lands or on privately owned lands where the use of native material is federally mandated or encouraged. This has allowed an opportunity for the relatively large, though fluctuating, amounts of Federal funding available there to support the development of a native seed industry, a situation that has occurred in few other countries. For most large-scale revegetation activities in the United States, the demand, until recently, has been for large quantities of a small number of species. In this case a formal breeding and selection program can be justified. Requests for additional species or ecotypes are frequently not filled due to lack of commercial seed production or wildland harvesting. Such species must be obtained through advanced planning and contracting for seed collection and field production. The Pre-variety Germplasm Release program provides a means for addressing the local ecotype issue in a more systematic and cost-effective manner. Despite the large amounts of funding to support the American network of Plant Materials Centres, the CRP, and the growing landscape-scale restoration and post-fire rehabilitation efforts, native grasses still account for less than 5 % of the grass seed sold nationally. In contrast, the Australian native grass seeds industry has been developing around the pastoral industry to meet the needs of private landholders. It is a comparatively new and developing industry, contributing considerably less than 1 % of the grass seed sold (Smith & Whalley 2002). The scale of revegetation activities in the Unites States may be considerably larger than that of Australia. However, the two countries have similar problems of seed supply and a fluctuating market.

For most large-scale revegetation activities in agricultural areas of Australia, the demand has also been for large quantities of a small number of productive species. Under PBR, cultivars must meet the requirements of distinctness, uniformity and stability, thus providing material with a relatively narrow genetic base. However, for these cultivars to be commercially successful they must also have a broad adaptive geographic range. In these cases it may be appropriate to undertake a formal breeding and selection program where the cost of developing, testing and releasing cultivars can be justified. Australian conventional plant breeding or selection programs, however, have not provided a means of ensuring that adequate supplies of reasonably priced seed are available for grassland restoration programs. Smith and Whalley (2002) suggest, that the first step towards the expanded successful use of native grasses should be determining the need and choosing an appropriate species for use in a selection program. For example, releasing a cultivar because it is native will not necessarily result in its successful use. In Australia there is no on-going commitment from federal or state agencies towards the continued development of native grass cultivars as there is in the United States with the Plant Materials Centres. In part, this has been due to difficulties in large scale commercial seed production of the limited number of released Australian cultivars, and a resultant poor track record. More importantly, there has also been a growing concern, in particular among private landholders, that broadly adapted cultivars do not represent the best material to be used in revegetation programs.

As an alternative to bred cultivars, the Canadian ecovars ™ or ecological varieties have been developed to provide material with both genetic diversity and improved growth characteristics. Thus, ecological varieties offer an intermediate degree of genetic variability, in which the natural variability of a species is maintained whilst some desirable characteristic(s) such as seed production is improved (Phan & Smith 2000). The desire to consider material with a wide genetic base is matched in the United States. Added to this, addressing issues of biodiversity for plant community restoration in the United States and by Australian Landcare groups, have focused attention towards harvesting seed of many species from wildland stands.

Locally harvested native material and Ecovars ™ are both likely to have a limited market potential and a highly fluctuating demand for supply. To address these issues, government agencies can, in the short-term, store large stocks of seed to meet revegetation requirements when demand outstrips the commercial supply. This has been achieved to some extent by the BLM in the United States. In the long term, once broad community acceptance of sowing adapted native grasses has been gained, this requirement may decline. Whilst the native grass seeds industry in Australia currently relies heavily on sourcing seed from wildland stands, seed sourced in this manner alone will not solve all the problems of seed supply. The areas requiring urgent revegetation usually lack suitable remnant stands or local seed supply is determined by local seasonal conditions. However, to support the development of this end of the industry and to realise the true value of local genotypes or wildland collections two considerations are essential. Firstly, a system of certification and labelling must be established to verify the origin and the quality of seed lots. The implementation of the American pre-variety germplasm standards has allowed the United States to successfully utilise wildland harvested seed as well as many partially selected lines. However, neither the 'source identified' nor 'selected' categories have counterparts in Australia. The adoption of similar standards may facilitate further development of a wildland seed collection industry and allow the selection and manipulation of superior genotypes with substantially less effort than is currently required under PBR or trademark releases. Secondly, the delineation of a seed provenance or adaptive seed collection zone will assist in determining the adaptive range of locally harvested material. Currently the lack of such information is a major limitation to using local provenance material. Whilst there have been some attempts at determining native grass/forb seed provenance zones (Bradshaw 1960, Millar & Libby 1989, Jones & Johnson 1998), knowledge of the ecological characteristics of species, and their response to environmental conditions is limited.

Meeting the future revegetation requirements of Australia and the United States will require utilising both selected and partially selected native plant material as well as sourcing seed from wildland stands. Irrespective of the type of plant material used in revegetation, meeting the demands for local seed supply is currently prohibiting the expansion of the native grass seed industries in both countries. Local seed supply issues are best addressed on a regional or catchment basis because of the variation in site characteristics, seasonal factors and revegetation priorities. This will allow priorities and strategies for addressing revegetation needs to be included as a component of natural resource planning. The development of community regional organisations such as Catchment Management Boards is a significant feature of natural resource management in Australia. These organisations will provide the future direction for federal funding of revegetation activities, acting as the counterpart to the Federal agencies in the United States in stimulating the native seed industry. Without the support and development of a strategic framework within such organisations native grass seed industries will fail to expand at a sufficient rate to meet global restoration or revegetation requirements.

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6. REFERENCES

Alderson J & Sharp WC 1994. Grass varieties in the United States. Agriculture Handbook 170. USDA Soil Conservation Service, Washington, DC.

Anon 1992. Productive land management options for the southern Avoca catchment. Avoca Dryland Salinity Management Plan Discussion Paper. DCNR Centre for Land Protection Research, Bendigo, Victoria.

AOSCA 1997. Seed certification tags and nomenclature for plant germplasm types. In: Genetic and Crop Standards of the Association of Official Seed Certifying Agencies, 1-12—1-14. Association of Official Seed Certifying Agencies, Beltsville, Maryland.

Barr N & Cary J 1992. Greening a brown land: The Australian search for sustainable land use, 6-117, MacMillan Education, Australia, Melbourne, Victoria.

Beisel A 1983. Harvesting chaffy grass seed with the Woodward Flail-Vac Seed stripper. In: Wiedemann HT & Cadenhead JF (eds.). Range and Pasture Seeding in the Southern Great Plains, 55-59, Texas A & M University, College Station, Texas.

Bermant D & Spackeen S 1997. Native species in the commercial seed industry. In: Shaw NL & Roundy BA (comps). Proceedings: Using Seeds of Native Species on Rangelands, 26-29. Gen. Tech. Rep. INT-GTR-372. USDA Forest Service, Ogden, Utah.

Bradshaw AD 1960. Population differentiation in *Agrostis tenuis* Sibth. III. Populations in varied environments. New Phytologist 59: 92-103.

Campbell A 1994. Landcare: Communities shaping the land and the future, 10-36. Allen and Unwin, St Leonards, Australia.

Clinton WJ 1999. Executive Order 13112—Invasive species. Federal Register 64: 6183.

Coram J, Evans WR & Dyson, P 2002. An evaluation framework for dryland salinity. National Land and Water Resources Audit. Dryland Salinity Program. National Heritage Trust, Kingston, ACT.

Donald CM 1970. Temperate pasture species. In: Moore RM (ed.). Australian Grasslands, 303-320. Australian National University Press, Canberra, ACT.

Englert JM, Kujawski JL, Scheetz JG 2002. Improved conservation plant materials released by NRCS and cooperators through September 2001. USDA Natural Resources Conservation Service, National Plant Materials Center, Beltsville, Maryland.

FloraBank 2002. Guidelines. Online: http://www.florabank.org.au/ [Accessed: 22/10/02]

Griffin GF 1993. The spread of buffel grass in inland Australia: Land use conflicts. In: Proceedings of the 10 Australian Weeds Conference and 14th Asian Pacific Weed Science Society Conference, 501-504. Brisbane, Queensland.

Harrington GN, Wilson AD & Young MD 1984. Management of rangeland ecosystems. In: Harrington GN, Wilson AD, Young MD (eds.). Management of Australia's Rangelands, 3-14, CSRIO, Melbourne, Victoria.

Hodgkinson KC, Harrington GN, Griffin GF, Noble JC & Young MD 1984. Management of vegetation with fire. In: Harrington GN, Wilson AD, Young MD (eds.). Management of Australia's Rangelands, 141-156. CSIRO, Melbourne, Victoria.

Johnston PW 1990. Producing native seed for mulga lands. In: Dowling PM & Garden DL (eds.). Native Grass Workshop Proceedings, 161-162. Australian Wool Corporation, Melbourne, Victoria.

Johnston WH, Clifton CA, Cole IA, Koen TB, Mitchell ML & Waterhouse DB. 1999. Low input grasses useful in limiting environments (LIGULE). Australian Journal of Agricultural Research 50: 29-53.

Jones TA 1990. A viewpoint on Indian ricegrass research: Its present status and future prospects. Journal of Range Management 43: 416-420.

Jones TA 1997. The expanding potential for native grass seed production in western North America. In: Landis TD & Thompson JR (tech. cords.). National Proceedings, Forest and Conservation Nursery Associations. USDA Forest Service, Portland, Oregon.

Jones TA 1998. Viewpoint: The present status and future prospects of squirreltail research. Journal of Range Management 51: 326-331.

Jones TA & Johnson DA 1998. Integrating genetic concepts into planning rangeland seedings. Journal of Range Management 51: 594-606.

Leigh JH 1990. Pastoral value and production from native pastures. In: Dowling PM & Garden DL (eds.).

Lodge GM 1996. Temperate native Australian grass improvement by selection. New Zealand Journal of Agricultural Research 39: 487-498.

Ludwig JA & Tongway DJ 1995. Desertification in Australia: An Eye to grass roots and landscapes. In: Mouat, DA & Hutchinson CF (eds.). Desertification in Developed Countries. International Symposium and Workshop on Desertification in Developed Countries: Why Can't We Control It ? Reprinted from Environmental Monitoring and Assessment, Vol. 37(1-3): 231-237. 1995. Kluwer Academic Publishers, Netherlands.

Matherson B 1996. Land care: rural property planning, 125-129. Inkata Press, Melbourne, Victoria.

Millar CI & Libby WJ 1989. Disneyland or native ecosystem: Genetics and the restorationist. Restoration and Management Notes 7: 18-24.

Monsen SB & Shaw NL 2001. Development and use of plant resources for western wildlands. In: McArthur ED & Fairbanks DJ (comps.). Shrubland Ecosystem Genetics and Biodiversity: Proceedings, 47-61, USDA Forest Service, Ogden, Utah.

Mortlock W 1999. Native seed in Australia: A survey of collection, storage and distribution of native seed for revegetation and conservation purposes – A report to the FloraBank project. Greening Australia, Canberra, ACT.

Mouat DA & Hutchinson CF (eds.). 1995. Desertification in developed countries. International symposium and workshop on desertification in developed countries: Why can't we control it? Reprinted from Environmental Monitoring and Assessment, Volume 37, 1-3, 1995. Kluwer Academic Publishers, Netherlands.

NHT 2002. The Natural Heritage Trust: Helping Communities Helping Australia. Online: http://members.ozemail.com.au/~upafed/Policy/nht2.htm [Accessed: 29/11/02].

Noble JC 1997. The delicate and noxious scrub: CSIRO studies on native tree and shrub proliferation in the semi-arid woodlands of eastern Australia, 77-125, CSIRO.Australia.

Pellant M & Hall C 1994. Distribution of two exotic grasses on Intermountain rangelands: status in 1992. In: Monsen SB & Kitchen SG (comps.). Proceedings – Ecology and Management of Annual Rangelands, 109-112. Gen.Tech. Rep.INT-GTR-313. USDA Forest Service, Ogden, Utah.

Phan AT & Smith SR 2000. Seed yield variation in blue grama and little bluestem plant collection in southern Manitoba, Canada. Crop Science 40: 555-561.

Roundy BA, Shaw NL & Booth DT 1997. Using native seeds on rangelands. In: Shaw NL & Roundy BA (comps.). Proceedings: Using Seeds of Native Species on Rangelands, 1-8, USDA-FS, Ogden, Utah.

Royal Commission 1901. Royal Commission to inquire into the condition of the crown tenants of the Western Division of New South Wales. Part 1. Report and summary of evidence. Cited in: Noble JC 1997. The Delicate and Noxious Scrub: CSIRO Studies on Native Tree and Shrub Proliferation in the Semi-Arid Woodlands of Eastern Australia.

Rue S 1995. The performance of selected native grass species when used for rangeland rehabilitation in central Australia. Northern Territory Department of Lands, Planning and Environment Resource Management Division Technical Memorandum No. TM 95/4.

Seed Industry Association of Australia 2002. National code of practice for seed labelling and marketing. Online: http://www.sia.ans.au/ [Accessed 22/10/02]

Smith M 2001. Managing TSR's for biodiversity and Seed Orchards. Final Report to the Natural Heritage Trust. AA0130.97. Rural Lands Protection Boards Association, Orange, New South Wales.

Smith SR & Whalley RDB 2002. A model for expanded use of native grasses. Native Plants Journal 3: 38-49.

STIPA 2002. STIPA Native Grasses Association. Online: http://www.stipa.com.au/ [Accessed 22/10/02]

USDA 2002. United States Department of Agriculture. History of the CRP. Online: http://www.fsa.usda.gov/dafp/cepd/12crplogo/history.htm [Accessed 22/10/02]

USDI/USDA 2002. Report to Congress: Interagency program to supply and manage native plant materials for restoration and rehabilitation on Federal Lands. U.S. Department of the Interior/U.S. Department of Agriculture. Washington, DC.

Warn D 2002. Seed Orchards – Practicalities at a local level. In: Proceedings of 'Smart Seed' Native Seed Forum. Parkes Victoria, 46-49. Greening Australia, Parkes, Victoria.

Waters CM & Monsen SB 1999. Stop, Proceed with caution: Recommendations for the developing Australian native grass seed industry. In: Proceedings of Third Australian Workshop on Native Seed Biology for Revegetation, 43-47. Australian Centre for Mining Environmental Research, Perth, Western Australia.

Waters C, Whalley W & Huxtable C 2000. Grassed-up: Guidelines for revegetating with Australian native grasses. NSW Agriculture, Orange, New South Wales.

Weaver JF 1954. North American prarie. Johnson Publishing Company, Lincoln, Nebraska.

Wilson AD 1996. Native and low input grasses for pastoral and marginal cropping land. New Zealand Journal of Agricultural Research 39: 465-469.

Whalley RDB 2000. Native Pasture Research on the slopes and tablelands of Australia – An historical overview. Proceedings of the 1st STIPA Native Grasses Association Conference, 1-9, STIPA, Mudgee, New South Wales.

Young SA, Kitchen SG, Armstrong J & Watson VH 1995. AOSCA approves certification guidelines for wildland collected seed. Seed World 133: 20-21.

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