The potential of native grasses for use as managed turf

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Abstract
Of the more than ten thousand species in the grass family some twelve species, divided more or less equally between the C_3 and C_4 groups, probably account for over 90% by area of the world's managed turf.

Many of the species in this small group are extensively naturalized across the globe (e.g. *Lolium perenne* in temperate regions and *Cynodon dactylon* in warm regions) and widespread differentiation into ecotypes has taken place. These local ecotypes have been commercially exploited for turf for centuries, while significant breeding effort has been devoted to the most important turf species over the last 50 years. As a result, it is difficult to launch unfamiliar native species into a tightly defined market already supplied with an abundance of cultivars and ecotypic selections of the standard species.

However, as greater demands are placed on turf for high performance under increasingly difficult environmental conditions, opportunities are opening up for (i) the addition of new species to the standard list and (ii) the transferring of unusual adaptive traits found in some native grasses to traditional turf species. This review examines the potential of four native species and one native genus for use in one or both of these ways: from Australia *Microlaena stipoides, Sporobolus virginicus,* the *Agrostis aemula* complex and the genus *Austrodanthonia,* and from North America *Buchloe dactyloides.* The current status of developmental work on these plants is assessed against a twelve-point check-list of biological and technological requirements for successful entry to the turf market. In general, the findings are that much remains to be done.

Media Summary
Intensified R&D is required to improve the performance of native turf forming species if they are to gain acceptance on golf courses and playing fields.

Keywords
plant breeding, turf selection criteria, recreational turf, environmental turf

Scope and Approach

Interest in the use of native species of grasses and grass-like plants for managed recreational and environmental turf has increased rapidly in the last fifteen years, mainly driven by the perception that the "natives" require fewer management inputs and therefore have a role to play in the development of more sustainable turf systems.

Given the large scale and well established nature of the turf industry, there are clear industry requirements and performance benchmarks that must be met if a "new species" is to gain acceptance and achieve either a viable share of the mainstream market or a small but stable share of a specialized niche market. The approach in this review will, therefore, be that of a plant breeder called upon to undertake the domestication of a number of wild species. It is understood that this work would include modification of their adaptation and behaviour to meet the requirements of an industry whose final product is highly visible to the general public and subject to intense scrutiny on both practical and aesthetic grounds

The review will focus mainly on the potential of native species for employment as managed recreational turf, by which is meant turf for applications such as sports fields and lawns which are subject to wear as a result of regular foot traffic and require plants possessing turf forming traits in a high degree. This will be followed by a brief consideration of the potential of natives for managed environmental turf, which, in contrast to recreational turf, is not subject to regular foot traffic, and whose principal roles are the prevention of erosion, the provision of habitat and the aesthetic enhancement of areas such as roadsides, roughs on golf courses and car parks.

Development of new crop varieties from wild plants: general principles
A convenient summary of the process of development of new crop varieties is provided by Simmonds (1979) and reproduced here as Figure 1. Note the large number of steps and the many processes and operations between the wild species and the ultimate release of a new variety for commercial use. These processes and operations all require knowledge and techniques which in the case of a “new crop”, means that an extensive research and development programme is needed to provide information as diverse as the cytology of the reproductive system and the most effective technique for harvesting the seeds. Clearly, an important decision for the plant breeder is whether the cost and time commitment that the exercise would involve is likely to be financially remunerative in the medium term.

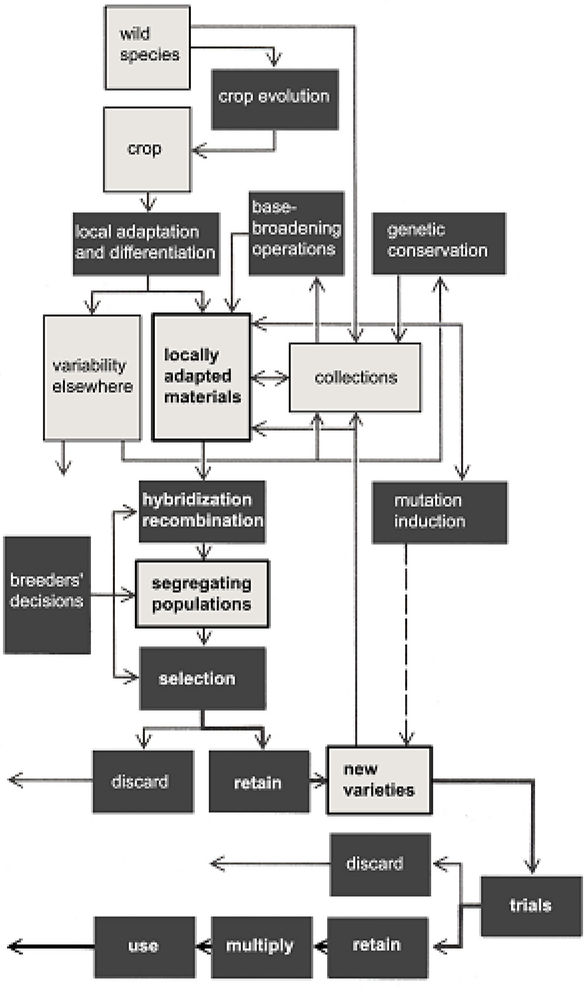

Figure 1. Development of new crop varieties. Diagram reproduced from Simmonds (1979)

Of particular importance in making the decision to proceed or not are (i) the extent to which the wild species has undergone “crop evolution” (see Figure 1) and (ii) the extent to which the benefits which the new species would bring into varieties bred from it could not be more economically achieved by expending further effort on the development of improved forms of the standard species.

Crop evolution of the standard turf species
Cool season species
William Davies, in Chapter II of his classic book “The Grass Crop” (Davies 1952) provides a graphic description of the way in which mankind, in the higher rainfall parts of the world, has for thousands of years transformed forested country into grassland and has maintained it as grassland by a management system based on the grazing animal. He goes on to explain that in England and Wales, on fertile soils a management system involving close grazing and heavy stocking typically leads to a pasture dominated by ryegrass and white clover, while on soils of poorer quality “an equally severe system of defoliation may induce herbage in which *Agrostis* and white clover are the dominants, while on moorland soils of low

inherent fertility, long continued close cropping of the herbage will often establish an *Agrostis*/fescue pasture, characteristically devoid of all legumes".

In accordance with the principles laid down by Davies, it is generally accepted that European lawns had their origin in the very heavily grazed areas adjoining early human settlements and were composed of the handful of species capable of enduring close and regular defoliation and trampling by sheep and goats. Further, in many situations of this kind the selection pressure was intensified by rabbits which nibble the grass even more closely than sheep. Bower (1911), in his pioneering study of the ecology of natural golf links in Scotland, observed that the finest turf with the best playing characteristics was always found in areas grazed by both sheep and rabbits. In short, the "crop evolution" of cool season turf species has been a long-continued process of selection acting on the most grazing tolerant, sward forming pasture species of the temperate and cool temperate zones.

Warm season species

The warm season turf species are more diverse in geographical origin and ecological habitat than the cool season species (Hartley 1950, Hartley and Williams 1956). Some of the them are important as pasture grasses (e.g. *Cynodon dactylon*, *Axonopus affinis* and *Pennisetum clandestinum)* or range-land grasses (e.g. *Buchloe dactyloides*) and have developed in a similar way to the cool season turf grasses through their ability to adapt to the selection pressures imposed by close and sustained grazing by a wide range of herbivores, including in many instances members of the ox group. Others (e.g. the *Zoysia* spp. and *Paspalum vaginatum)* are limited in the wild to special habitats where they form a short dense turf even in the absence of grazing.

The transition of the leading warm season turf forming grasses from "wild species" to "crop species" is less well documented, but it is clear from the writings of Maiden (1898) that *Cynodon dactylon* had long been highly esteemed as a lawn grass in the warm temperate regions of the world, while exploitation of *Stenotaphrum secundatum* as a lawn grass goes back at least to about 1800 (Sauer 1972).

Exploitation of species for recreational turf

Historically the transformation of a "wild species" into a "crop species" involved not only crop evolution as discussed above, but also exploitation in which promising material was tried and those kinds found to give satisfaction without excessive demands gradually passed into commercial use.

With the emergence of large-scale landscape gardening in Europe during the 17th Century, there developed a commercial demand for "instant lawns", but in the absence of a turf seed production industry, the need was met by cutting turves (sods) from commons and other intensively grazed lands. Having laid such turf, it was found necessary to give it regular close defoliation in order to retain the desired tight, dense, hard-wearing sward, but the only practical means available at that time were the folding of sheep upon the area or the laborious process of trimming by scythe. The patenting of a lawn-mowing machine by Edmund Budding in 1830 and its promotion through the *Gardener's Magazine* in 1832 (Beard 1973, Hadfield 1969) led to an almost immediate increase in the area of land devoted to managed recreational turf and to a significant production of turves and turf seed in Britain, France and North-Eastern USA from as early as 1850.

The principal turf species

The grasses and "grass like plants" such as sedges and rushes have a worldwide distribution and in aggregate amount to about 15,000 species (Gramineae/Poaceae approximately 10,000 (Clayton and Renvoize 1986), Cyperaceae about 4350 species (Mabberly 1997) and Juncaceae about 430 species (Mabberly 1997)). Despite the huge number of species in the three main candidate families, only a tiny percentage is capable of withstanding regular close defoliation and fewer still (and these are all grasses) are capable of displaying the desirable morphological plasticity which leads, under these conditions, to increased tiller numbers per unit area and decreased leaf width.

Watson (1994) states that about forty species of grass can be categorized as turf forming, but my inquiries suggest that fewer than twenty five of these species are recognized commercially in the formation of turf and that many of these are of minor importance. The following lists, based on many sources, both scientific and commercial, cover the species which probably account for over 90% by area of the world's managed turf:

- cool season (C_3) grasses, Lolium perenne, Agrostis stolonifera, Agrostis tenuis, Festuca arundinacea, Festuca rubra and Poa pratensis
- warm season (C_4) grasses, Cynodon dactylon (including its interspecific hybrids with C. transvaalensis), Stenotaphrum secundatum, Zoysia japonica, Axonopus affinis, Pennisetum clandestinum and Paspalum notatum.

Interestingly, the massive expansion of the area of managed turf in the last 100 years has not been accompanied by a corresponding increase in the range of species employed. During that period there has been little change in the composition of the "main species" list, and many of the other traditional turf-grasses have remained throughout with a steady but small market e.g. *Festuca ovina*, *Digitaria didactyla* and *Eremochloa ophiuroides*. On the other hand, a few species which were previously recognized as useful for turf only in special habitats have been shown by recent research to be of wider application and accordingly are increasing in importance e.g. *Paspalum vaginatum* (Duncan 1997a, 1997b) and *Buchloe dactyloides* (discussed later in this paper).

Many of the traditional turf species are extensively naturalized across the world (e.g. *Lolium perenne* and *Agrostis tenuis* in temperate regions, *Cynodon dactylon* and *Stenotaphrum secundatum* in warm regions) and widespread differentiation into ecotypes had taken place. These local ecotypes have been exploited for turf for a very long time, in some cases for centuries, while almost all the more important species have been the subject of intensive breeding programmes over the last 50 years. These factors serve to reinforce the dominance of the traditional species. It is against this background that one must examine the potential of unfamiliar native grasses and grass-like plants with no history of crop evolution for entry into a tightly defined market already supplied with an abundance of cultivars and ecotypic selections of the standard species.

Criteria for undertaking an R&D Programme on a native species with turf potential

The criteria that I have developed at the Plant Breeding Institute for assessing the state of the information and technology base of native species compared with that of standard turf species is as follows:

Basic biological information

1. Does the wild species show good turf quality in the field either in closely grazed pastures or in a specialized habitat (e.g. saline area)?
2. Do the habitat preferences and general adaptation of the species in the wild give indications of at least some valuable adaptational features including factors such as shade tolerance, salinity tolerance, frost tolerance, and drought tolerance?
3. Is there a good range of variation in the wild in reasonably accessible areas to facilitate the building up of an adequate germplasm collection?
4. Do we have detailed information on vegetative and reproductive morphology together with notes on its systematic position in relation to other species in the same genus and to related genera, together with reports on ecological, physiological, cytological or other scientific aspects of relevance to the breeding of this species and related taxa?
5. Is anything known about its pollination ecology including time of pollen release, time of receptivity of the stigma, isolation requirements, variation in these particulars between lines or selections, pattern of flowering in the panicle and feasibility of hand crossing?
6. Can it be readily propagated for use in breeding programmes? Is any information available on germination requirements including breaking of dormancy? Is there any information on clonal propagation?

Turf performance aspects

1. What is the susceptibility of the parental lines and the progeny to common turf pests and diseases in the young and mature states?
2. Is there adequate tolerance of pesticides (including pre- and post-emergence herbicides) in the material from which selections for release will be made?
3. In terms of turf quality is there tolerance of the mowing heights which will be typical of the intended end use?

4. Have the selections proposed for release been checked to ensure that they do not have the potential to become either environmental or crop weeds?

Mass propagation technology

1. (a)For seed propagated varieties, have seed production techniques including general agronomy of the seed crop, harvesting, drying, and threshing and seed trade issues including storage, longevity, seed quality standards, and estimated value per kilo been determined? (remember turf species are typically sown at rates 20 to 40 times those used for pasture)
   (b) For vegetatively propagated species, have turf-forming requirements including climate, soil, establishment methods, general agronomy, frequency of cutting for sale, depth of cut, ease of rolling, thickness of cut, strength of rolls and probable value per square metre been determined?

Turf management requirements
Is appropriate trial data available covering comparative performance against standard turf varieties, and for the new material methods of establishment, height of cut recommendations, fertilizer requirements, renovation requirements, water requirements, management of wear, shade tolerance and pest management protocols?

Case Studies

Buchloe dactyloides
This grass was recognized as a turf-forming species capable of withstanding heavy grazing by buffalo and cattle by the early scientific observers of the grasses of the Great Plains of the USA (e.g. Vasey 1884), while Weaver and Clements (1938) noted the close association between overgrazed sites and the formation of an "almost unbroken sod of *Bouteloua* and *Buchloe*" (p. 525). Despite these encouraging indications of its potential as a cultivated turf in the sub-humid and semi-arid zones of the USA, Beard (1973) reported that no turf cultivars had been developed by that date.

However, with increasing interest in low rainfall districts in the replacement of turf requiring regular irrigation by hardier types, *Buchloe dactyloides* has attracted a concentrated research effort in recent years.

A selection of the information now available for *Buchloe dactyloides* used as turf follows: general adaptation of the species highlighting its low water and nutrient requirements (Johnson 2000, Diesburg et al. 1997); on drought tolerance and genotypic variation in comparative evapotranspiration rates (Qian and Fry 1997, Bowman et al.1998), on superior performance to standard turf grasses under conditions of restricted irrigation (Qian and Engelke 1999, Smeal and O'Neill 2004); on polyploid variation (Johnson et al. 2001), the breeding system (Quinn 2000), tissue culture (Niu et al. 1997), selection indices (Klingenberg and Riordan 1997), inheritance of caryopsis weight (Rodgers et al.1997) and genotypic variation in sward dormancy behaviour (Kenworthy et al. 1999); on agronomic matters such as mowing height (Johnson et al. 2000), herbicide tolerance (Dotray and McKenney, 1996, Fry et al. 1997), freezing tolerance (Qian et al. 2001) salt tolerance (Lin and Wu 1996), and various aspects of establishment from seed including burrs versus caryopses (Riordan et al.1997, Gaitan-Gaitan et al. 1998), planting date (Gaitan-Gaitan et al. 1998, Frank et al. 1998), depth of planting (Heckman et al. 2002), and influence of fertilizers on establishment rate (Frank et al. 2002); on vegetative establishment from plugs (Johnson et al. 1997) and on sod-production characteristics (Giese et al. 1997); on insect pests (e.g. Johnson-Cicalese et al. (1998) on mealy bug resistant germplasm) and fungal diseases (e.g. Tisserat et al. (1999) on spring dead spot). Many new varieties have been released (e.g. "61 Buffalograss" (Johnson et al. 2000), "118 Buffalograss (Riordan et al. 2000) and "120 Buffalograss" (Johnson-Cicalese et al. 2000)), some of which provide excellent turf quality with mowing heights as low as 1.6cm. In addition, trials are being carried out on mixtures with other low-maintenance grasses to extend the green period (Johnson 2003) and trials of the grass outside the USA have been reported from Hangzhou, China (Niu et al. 1997) and Tuscany, Italy (Miele et al. 2000).

As can be seen from the preceding paragraph, the recent research effort on *Buchloe dactyloides* has so increased the understanding of the adaptation, breeding and agronomy of the species as a managed turf that it is now approaching the point where it can enter the turf market on equal terms with the widely used traditional species.

Microlaena stipoides

Rice Grass, *Microlaena stipoides* (Labill.) R.Br. is a perennial Australasian C_3 grass with an exceptionally wide latitudinal distribution in the better watered parts of Australia and Northern New Zealand. Although the generic name *Microlaena* is strongly defended by Australasian agrostologists (e.g. Wheeler et al. 2002) many European authors treat it as a section of the genus *Ehrharta*, so that information on the species in question will be found in these sources under the name *Ehrharta stipoides* Labill. (e.g. Clayton and Renvoize 1986). It was noted as a useful pasture grass by the early settlers and Mueller (1881, p.111) reported that Mr W.H. Bacchus of Ballarat, Victoria, found the grass "to bear overstocking better than any other native grass, and to maintain a close turf". Mueller also noted that it "kept beautifully green throughout the year" but that it was "not always copiously seeding".

In the cooler parts of Australia it has been a common experience of gardeners throughout the 20th Century to find forms of *Microlaena stipoides* appearing spontaneously in non-irrigated lawns, especially in shady areas. This is interesting in terms of the concept of wild species undergoing "crop evolution" (Simmonds 1979). We know form the evidence of Bacchus (in Mueller (1881)) that there were forms of the grass which responded to close grazing by forming a close turf, and a little later we have gardeners reporting that forms of the grass with a distinct turf habit had colonized and were persisting in regularly mown lawns composed predominantly of traditional cool season grasses such as *Lolium perenne, Festuca rubra* and *Poa pratensis.* Gardeners have also noted that, much as described by Mueller, the *Microlaena* remains green even in times of drought, and as well is reasonably frost tolerant and shade tolerant. To a plant breeder this suggests a native species with the capacity to respond quickly to new selection pressures and therefore well worth further examination for its turf potential.

Jones and Whalley (1994) reported that examination of an extensive collection of *Microlaena stipoides* ecotypes at the University of New England (Armidale, NSW, Australia) revealed at least two lines which were capable of forming a good lawn under regular mowing at sowing densities of 10,000 seeds per square metre. Mowing on a weekly basis led to formation of a better turf than mowing at two or three weekly intervals. Whalley (1995) stated that *Microlaena stipoides* probably has the greatest potential of any Australian native grass for development as a turf species. Whalley (1990) noted that it had a flexible breeding system with three distinct sorts of flowers, including cleistogamous spikelets within the lower leaf sheaths.

Despite this promising situation, little has been done to develop the species for serious turf use. From the University of New England collection several ecotypes have been placed into Plant Breeders' Rights protection including "Griffin" for turf use and "Shannon" for roadside work and golf course roughs. Chivers et al. (1997) reported the results of a series of small trials at Melbourne (Victoria, Australia) which explored some agronomic aspects of establishment from seed including depth of planting and husked versus intact seeds as well as demonstrating tolerance of two of the five pre-emergence herbicides tested. There have been a small number of published studies dealing with *Microlaena stipoides* since 1997, but most of them are concerned with its management in native pastures.

Cole et al. (2003) examined the tolerance of three important native pasture species including *Microlaena stipoides* to nine post-emergence herbicides of potential use for the control of annual weeds in crops of these species being grown for seed production. Although not specifically directed at turf ecotypes, it is disappointing to note that of the nine post-emergence herbicides tested the pasture type of *Microlaena* employed was fully tolerant of only one of them and highly intolerant of four.

In a study of ground-covers suited to the shady conditions in mature Macadamia plantations, Firth et al. (2002) found that *Microlaena stipoides* cv. "Wakefield" performed well but was, overall, not as suitable as *Dactyloctenium australe*. In contrast, under the exposed conditions of the roadside environment in the Northern Tablelands of New South Wales, Huxtable and Whalley (1999) found that *Microlaena stipoides* was capable of satisfactory establishment from spring sowings on a prepared seedbed given adequate rainfall, as well as giving satisfactory results if sown into a dry seedbed in summer and relying on autumn rains to induce germination.

Although some progress has been made in the understanding of the potential of *Microlaena stipoides* as a turf grass, it is obvious that in terms of the twelve areas of information required for the successful breeding, mass propagation and utilization in the industry, work on this species has scarcely commenced. Amongst other things, future studies must focus on reducing the price of seed: Australian seed suppliers are currently quoting prices in the vicinity of A$180 per kg, which, with a recommended sowing rate for turf of 1kg per 100m^2, would run out at $18,000 per hectare for seed alone.

The genus Austrodanthonia
The Australian grasses previous classified as belonging to the genus *Danthonia* are now segregated into two new genera, the majority in *Austrodanthonia* and the balance in *Notodanthonia* (Wheeler et al. 2002). These grasses have long been recognized as important components of native pastures in Australia and Cashmore (1932) drew attention to the fine leaves and tolerance of close grazing of many of the species. Subsequent work has led to an improved understanding of the value of these grasses in native pastures, particularly in harsh, non-irrigated environments on acid soils (see Garden et al. (2001) for the results of an extensive survey in the Tablelands of New South Wales).

Lodge and Whalley (1981) studied the influence on temperature on germination of a number of important native pasture species, including *Austrodanthonia bipartita* (syn. *Danthonia linkii*). Lodge (1981) examined establishment and seedling survival of the same species in the field. Huxtable and Whalley (1999) assessed the establishment and survival of *Austrodanthonia richardsonii* (syn. *Danthonia richardsonii*) in roadside plantings in the Northern Tablelands of New South Wales, concluding that spring sowing into a prepared seed bed gave the best results but satisfactory results could also be obtained by sowing into a dry seed bed in summer and waiting for the autumn rains to bring about germination and establishment. Studies such as these, together with the release of selected forms by New South Wales and Victorian Government agencies, the CSIRO and private seed companies, have led to increased confidence in the deliberate planting of *Austrodanthonia* spp. for land reclamation projects, roadside re-vegetation and environmental turf situations such as roughs on golf courses. However, in terms of more intensively managed turf such as lawns, the best that is available at present withstands only light foot traffic and requires a mowing height of 50mm or more.

Once again, the price of seed is a serious issue, with seed in the form of the fluffy florets costing about A$90 per kg, while cleaned seed (i.e. seed less florets and hair tufts) is about $450 per kg. Research into seed crop management of *Austroodanthonia richardsonii* and *A. bipartita* by Lodge (2002) has shown that the crops are difficult to manage for increased yields of viable seed and that more research is needed. Post-emergence herbicide trials for seed crops (Cole et al. (2003) have also given disappointing results, the seedlings of *Austrodanthonia fulva* proving to be sensitive to seven of the nine products used and tolerant of only one.

Although showing considerable potential for use in environmental turf, it is becoming clear that the potential of members of the genus *Austrodanthonia* for use as intensively managed turf for lawns and sports is very low and that attention should be directed elsewhere.

Sporobolus virginicus
Sand Couch or Marine Couch, *Sporobolus virginicus,* is a C_4 grass found in salt-marshes and in littoral situations throughout the tropics and warm temperate zones of the world. It is generally less than 40cm high and frequently forms dense turf-like mats as short as 3-5cm in the wild. Not surprisingly, given its habitat preferences, it is highly salt tolerant, being rated by Marcum (1999), together with *Distichlis spicata* var. *stricta*, as the most salt tolerant of all turf grasses. However, it also grows well in low salinity and non-saline situations.

Its merits were commented upon at an early date. Mueller (1881 p.324) said of this grass that it “will luxuriate in sandy maritime places, and keep perfectly green after three or four months’ drought”, while Maiden (1898) recommended it for use as a coastal sand binder (p.7) and also commented (p.160) that “this grass has something of the habit of Couch grass (*Cynodon*), and is particularly valuable for saline situations. Cattle become readily accustomed to it, and it is a nutritious grass.”

In Australia two forms are recognised as botanical sub-species: one type, which has leaves more than 1mm wide grows on coastal margins including the littoral zone and is known as var. *virginicus* while the narrow-leaved form (leaves less than 1mm) grows in salt marshes and is known as var. *minor* F.M. Bailey (Wheeler et al. 2002). However, detailed cytological studies by Smith-White (1988) have uncovered a remarkable degree of ploidy-based population differentiation with ploidy levels as high as pentaploid. The same author has stressed the importance of vegetative reproduction in this species, even in populations whose ploidy level does permit seed production, and has further noted the occurrence of male sterility, agamospermy and in one pentaploid form vegetative proliferation of the spikelets. Clearly there is a vast pool of variation available in this species, but the information available to date throws little light on the adaptive significance of the ploidy levels for the guidance of plant breeders.

Regarding propagation, Frith (1957) has shown for a range of Western Australian accessions that maximum germination requires light, nitrate and alternating temperatures (15/35°C). At the production level vegetative propagation is the normal procedure, sprigs being used to establish individual plants in small plastic containers or for direct sprigging of larger areas. Once established in the field the rhizomatous nature of the grass permits it to be cut for rolled turfed and to regenerate from the rhizomes left behind, but the slow growth rate for initial establishment (up to two years) and for regeneration mean that productivity in terms of output of rolled turf per hectare per annum is low and consequently price per square metre is high.

Two bred cultivars have been placed into Plant Breeders' Rights protection in recent years by a private company in Australia ("Ozlawn" and "Nathus Green"), but uptake by the general lawn market has been very limited, primarily because of the lengthy time to become fully established (up to two years), the problems of managing weed invasion during that time, and its intolerance of close mowing. At this stage no scientific data is available on herbicide tolerance, but trade literature suggests reasonable tolerance of at least three common post-emergence herbicides. The "Ozlawn" cultivar, as seen in the demonstration plots at the Royal Botanic Gardens, Sydney, has formed a most attractive sward looking somewhat like Tall Fescue. It requires little mowing, has moderate wear tolerance, but like most of the slow-growing grasses native to specialised habitats, it is very slow to recuperate after wear.

The amount of research and development needed to put *Sporobolus virginicus* into a competitive position with more conventional grasses for use in lawns in non-saline habitats is so great that it is probably best to restrict its use to saline habitats where its special advantages in forming low maintenance turf for amenity or environmental purposes can be exploited with the material already available.

The Agrostis aemula complex

Two rather similar looking species of *Agrostis viz. A. aemula and A. avenacea* are described in Australian floras as having a wide natural distribution in non-alpine areas outside the tropical zone. The nomenclature of these grasses is somewhat unsettled, some authors such as Wheeler (2002) segregating them from *Agrostis* into the genus *Lachnagrostis*, an approach not accepted, however, by Clayton and Renvoize (1986). Many floras state that these species are found mainly in moist or wet situations (e.g. Beadle et al. 1972), but field work in Eastern Australia shows that although annual forms occur mostly in moist situations, there is a wide distribution in sub-coastal native pastures of perennial forms in sites which suffer frequent droughts (Martin, unpublished).

There also appear to be some difficulties in devising species descriptions sufficiently robust to accommodate all the forms of *Agrostis aemula* and *A. avenacea* within their respective taxa. Developmental studies with large populations suggest that many of the characters relied upon in keys and written descriptions to distinguish the two species are unreliable and there may be a need to redefine the group and designate at least one additional taxon (Martin, unpublished).

Perennial forms of these grasses are widely distributed on heavy soils in the Cumberland Plain, west of Sydney, and in similar sub-coastal situations in both the mid-North Coast and South Coast regions of New South Wales. In the field, some forms exhibit excellent drought resistance, high temperature tolerance and tolerance of dense soils, all characteristics which would be most welcome in extending the range of adaptation of the commonly cultivated fine sports-turf species *Agrostis stolonifera* and *A. tenuis.*

A large collection of perennial ecotypes of *Agrostis aemula* and *A. avenacea* has been assembled at the Plant Breeding Institute since 1992 and is subject to regular assessment. It has been found that most lines have fairly coarse leaves and none of them respond well to close cutting. The inflorescences are large and loose, bearing only a few hundred seeds each and with a strong tendency to break off whole and blow away in windy weather (hence the common name of “Blown Grass” applied to these species). However, stress testing showed that many lines had excellent drought tolerance and high temperature resistance.

It soon became apparent that it would be difficult or impossible to develop a quality turf grass from this material. The emphasis of my programme then shifted to exploring the possibility of transferring by hybridisation the desirable qualities of these species into the conventional turf species of *Agrostis.* However, the turf species of *Agrostis* are usually propagated by seed, so the inflorescence characters of the native material we were working with were seen as most unfortunate, especially the disarticulation behaviour. A few ecotypes had been noticed which had more strongly attached mature inflorescences, so these were used in a controlled crossing programme with lines possessing other desirable qualities. Selection of the progeny has now given us a number of lines which when sown as spaced plants under open field conditions show good retention of the inflorescence and seed two months after maturity. Further selection for drought tolerance and finer leaves within large populations of this improved material has now provided us with about 15 lines which will be used in experimental crossings with conventional turf species of *Agrostis.*

Preliminary cytological work has shown that high levels of ploidy exist in some of the native material. This could lead to difficulties in crossing and may necessitate the use of bridge species. However, the point of the story is clear. Rather than attempting to fashion highly unsuitable material into a new commercial turf grass, we have chosen to eliminate some of the most detrimental features from the wild material as a precursor to undertaking transfer of the desirable characters to the standard turf cultivars of *Agrostis* by hybridisation or if necessary by more advanced methods.

A note on environmental turf plantings

Environmental turf, in contrast to recreational turf, is managed turf that is not subject to significant foot traffic and generally receives a lower level of maintenance. The term covers a wide variety of situations stretching from rarely mown lawns to sensitive restorations of natural grassland types with significant bio-diversity. The management principles involved therefore extend from conventional turf management at a low intensity, to occasional toppings with a slasher on a high setting reminiscent of some forms of range management, to the creation of complete grassland communities requiring only occasional intervention to reduce the prevalence of aggressive species or to repair damaged areas.

Over the last twenty years there has been a growing interest in the idea that highly maintained recreational grass should be confined to sports fields, playgrounds and regularly used lawns and that less frequented areas such as the roughs of golf courses, remote zones of large public parks and roadsides should be converted to one of the types of environmental turf mentioned in the previous paragraph. The benefits of this approach are not only greatly reduced maintenance costs, but a welcome increase in habitat conducive to improved biodiversity and generally a more natural and pleasing appearance. Numerous publications have appeared covering the creation and management of these areas (e.g. Emery (1986) on grassland communities and meadows and Duell (1997) on roadside turf management). There are also indications that these types of plantings increase populations of beneficial arthropods which enhance natural pest management in nearby intensively managed sites (Thomas et al. (1992).

The use of native grasses and grass-like species is encouraged for these developments, and given the absence of the wear factor and the generally lower demands made on the plants in terms of absence of close mowing and other stresses, a much greater range of material becomes acceptable. In these situations, provided propagation requirements and effective transplantation or seeding techniques can be developed, the use of native species of local provenance rather than standard “landscaping” species should give excellent results. There is one important limitation, however, in the use of natives in the immediate roadside zone of high speed motorways: species and cultivars must be carefully chosen on the basis of either experience or experiment for their ability to handle wind-rush without undue tattering of the leaves.

Conclusion

This review has explored the idea that the small number of widely used turf grasses have not reached their present status by some accidental series of events, but have been found by experience to be the most useful of a small list of species with a generally similar "crop evolution" background. They are the products of natural selection associated in most cases with humans and their grazing animals, and in a few cases with the selective effects of highly specialised growth restricting habitats. The processes involved in the origin of the traditional turf grasses have led to a high degree of adaptation to the requirements of the situation. In addition, an extensive body of knowledge both scientific and technological has accumulated regarding their breeding and management.

Native species proposed for recreational turf have to meet stringent performance requirements if they are to gain commercial acceptance. Achieving these performance objectives will usually involve not only lengthy plant breeding research but extensive work on the agronomic side in mass propagation and turf management. It is concluded that most of the native species thought to have some turf potential would not repay the effort required to meet these requirements. *Buchloe dactyloides* is an exception to this conclusion because, not only does it offer outstanding advantages over the traditional species as a turf for use in drier districts, but it has been the subject of research and development of such comprehensiveness and intensity that its future commercialisation will proceed on a basis similar to that of the traditional turf species. As an alternative to attempting to develop native species into recreational turf species it is pointed out that the introduction of useful traits into accepted turf species from their native relatives may be a useful path to follow.

Finally, in relation to the potential of native species for use in environmental turf, the much less restrictive requirements for penetration into this market and a growing awareness of the use of biotypes of local provenance suggest a much easier path to commercialisation but overall a smaller total market per species.

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