Historical aspects of commercial weed invasions – perennial grass case studies

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Abstract

The historical aspects of commercial weed invasion are described from European settlement through to the recent issues of e-commerce and genetically modified crops. Weed status by industry sector is discussed comparing garden/ornamental, botanical garden, agricultural industries and accidental/contamination weed introductions using examples of Weeds of National Significance. A case study of a recently introduced weed to Australia, Mexican feather grass is discussed and how it highlighted an important anomaly in the plant import appraisal process prompting Biosecurity Australia to fully implement the permitted list system. A second perennial grass case study examines how a serious Australian weed, brown top bent grass management could be potentially compromised by inappropriate genetic modification research undertaken by a USA company seeking commercial profits. A list of proposed directions for dealing with weed invasion issues is presented.

Introduction

Weeds are costing Australia from $3.5–4.5 billion annually based on present day figures, $2.4 billion of which comes from livestock industries (Sinden *et al.* 2004). They are also causing severe impacts on the natural environment (Carr *et al.* 1992). Unpalatable grasses are one of the most serious threats facing farmers, causing huge agricultural losses and untold social hardships. Similarly, exotic grasses are invading indigenous grasslands and are serious environmental weeds (Carr *et al.* 1992).

Plants have always been a fascination, a desired commodity and a food source. They are introduced and distributed within Australia for gardening, landscaping, livestock food (fodder), fibre, turf, timber, floriculture, soil stabilization, salinity control and for medicinal purposes. One person's beautiful plant can be another's noxious weed. Over the past two centuries more than 27 000 species of exotic plants have been introduced into Australia. Of these, approximately 3089 species have now naturalized in Australia (Randall 2006). So what defines a weed? Some weed definitions include: A plant that is unwanted or destructive (Groves 1997); a native or introduced plant species that has a perceived negative ecological or economic effect on agricultural or natural ecosystems (Booth *et al*. 2003); a plant growing in an area where it is not wanted (Auld and Med 1992). It is inevitable that different people will have different views on what they consider beneficial and useful plant species and what is a destructive or damaging weed. Conflicts of interest are part of life and part of business, but how do we manage and deal with these conflicts of interest for the long term good of Australia's economic, environmental and social values?

Historically, weed management was only initiated once a weed had become a serious economic problem and emphasis was placed on weed species with high potential for fast dispersal (Auld *et al*. 1978). Today's management pays attention to the principle of 'prevention rather than cure' as opposed to a past philosophy of 'treating weed problems as they arise' (Csurhes and Edwards 1998). In retrospect, weed prevention, management and control have been and will continue to be an evolutionary process. By the early 1980s weed problems were increasingly recognized as having more than economic repercussions. In the status review 'Plant invasions of Australian ecosystems' (1991), Humphries, Groves and Mitchell identified changes to natural ecosystems, conservation status and species existence and abundance as consequences of weed invasions, in addition to agricultural costs and losses. The authors also emphasize that two management principles in particular are of utmost importance: (a) prevention is the most powerful tool there is and (b) intervention at an early stage of weed invasion is crucial. These principles are incorporated into current national and state weed legislation.

The Australian Weed Strategy (ARMCANZ 2007) has three clear objectives:

1. To prevent the development of new weed problems.
2. To reduce the impact of existing weed problems of national significance and
3. To provide a framework and capacity for ongoing management of weed problems of national significance.

Australia has progressed overwhelmingly in the area of weed management however there still remains a long way yet to go in the battle against weeds. Despite the protocols and procedures that have been developed to prevent legal import of weedy species, they are still getting in. There are two statutory opportunities to prevent weed issues arising. 1. by preventing entry of potential weeds at the national border via Australian Government quarantine restrictions and 2. by minimizing sale and interstate movement of weeds using State and Territory pest management legislation. This paper provides a short history of how weeds have entered Australia and how Government authorities have responded. It then examines two case studies of the unpalatable grasses, Mexican feather grass, (*Nassella tenuissima*) and brown top bent grass (*Agrostis castellana*).

Weeds in the garden/ornamental industry

During the early European colonization of Australia many plants such as gorse (*Ulex europaeus*) and willows (*Salix* spp.) (now Weeds of National Significance) were brought to Australia with settlers to remind them of their homeland. Many such early plant introductions were woody plants, presumably because they could survive the long sea voyage from Britain more easily than herbs (Groves 2004). Some, such as blackberry (*Rubus fruticosus*) were also introduced as a food source. Scotch thistle (*Onopordum acanthium*) was introduced for patriotic reasons as it represented the national flower emblem of Scotland (Parsons and Cuthbertson 1992). Private nurseries were operating in Adelaide in the 1840s and in Melbourne by the 1850s (Mulvaney 1991) and through time the ornamental horticultural industry has been the source for the greatest number of weedy species entering Australia (Figure 1). By 2004, approximately 25 160 exotic plant species had been introduced to Australia via the ornamental horticulture industry, of which 1366 species were naturalized and weedy (Virtue *et al.* 2004, Figure 1). On the positive side, only 5% of the species introduced by the ornamental horticulture industry have naturalized in Australia to date. However, more than 56% of all weedy species in Australia originated from plant species brought in for ornamental horticulture (Virtue *et al.* 2004, Figure 1). Some examples of such plants include the Weeds of National Significance rubber vine (*Cryptostegia grandiflora*), bridal creeper (*Asparagus asparagoides*), gorse, lantana (*Lantana camara*), willows and boneseed (*Chrysanthemoides monilifera*) (Parsons and Cuthbertson 1992). Similarly, the Weeds of National Significance aquatic weeds salvinia (*Salvinia molesta*) and cabomba (*Cabomba caroliniana*) are thought to have been introduced via the aquarium industry (Parsons and Cuthbertson 1992).

With the ever-continuing demand for new exotic ornamental plants, it is hardly surprising that strong competition exists between traders to expand product markets. Until the late 1970s, the problem of invasive garden plants becoming agricultural and environmental weeds was largely unrecognized. This issue is now well accepted by Government agencies who are working with the Nursery and Garden Industry Australia (NGIA) to minimize such impacts (Dempster 2002). The CRC for Weed Management Systems initiated a 'Garden Plants under the Spotlight' program (Blood and Randall 1998) which listed 100 'Garden Thugs' – weedy plants that should not be promoted for garden use. The later CRC for Australian Weed Management adopted and supported Weed Spotter programs involving networks of community volunteers and weeds officers across Victoria and Queensland to enable weed identification, prevention and early intervention.

Weeds via botanical gardens

Historically botanical gardens have also played a part in the introduction and dispersal of weeds. The role of botanic gardens has changed over time from a depository for interesting, beautiful, unusual, exotic, curious plant 'trophies' from around the world to centres that provide education about plant taxonomy, classification, heritage, science and more recently conservation of endangered species (Spencer 2006). Rightly or wrongly, Australian botanical gardens have had a poor reputation in relation to weeds. Blackberry and *Mimosa pigra*, both Weeds of National Significance, reportedly originated from collections from the Melbourne and Darwin botanical gardens respectively (Spencer 2006). However, Australian botanical gardens are now actively tackling the weed issue and in collaboration with the CRC for Australian Weed Management have developed an Australian Botanic Gardens Weed Network (ABGWN) with a membership of 75 organizations. With the formation of ABGWN it is hoped that botanic gardens can help stem the tide of invasive plants by: preventing the introduction to botanic gardens of species known or thought to have weed potential; prevention of dissemination of known weed species from botanic garden collections; reducing the impact of existing weeds by identifying and managing existing problem species and monitoring plants entering and leaving sites; developing a framework for continuing weed management through a co-operative exchange of information and development of agreed policies, procedures and a weed risk assessment methodology; and developing programs to educate and inform the community on weeds and weed issues (Spencer 2006).

Weeds via agriculture industries

Agriculture has been significant source of weeds and numerous grass and legume species introduced for forage have become significant weeds. *Hymenachne amplexicaule* for example was introduced into Queensland in 1989 for fodder but has since been recognized as a Weed of National Significance threatening Queensland's $2 billion dollar sugar industry. This issue has also been highlighted in the recent declaration of gamba grass (*Andropogon gayanus*) as a declared class 2 weed in Queensland. In this case, gamba grass was introduced (from South Africa) as a fodder species for the beef industry in Queensland and has since become a serious environmental weed and fire risk. Approximately 18% of the 1300 plant species introduced into Australia for agricultural production (cropping, pasture and forestry) have become weedy species (Virtue *et al.* 2004, Figure 1), and many such as gamba grass are having major environmental impacts.

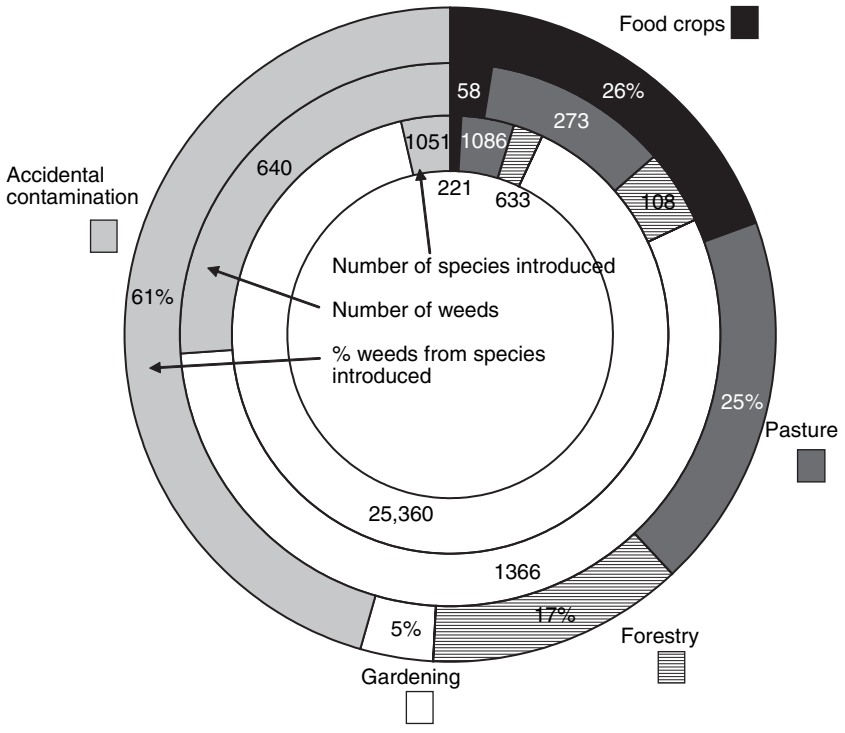

Figure 1. Weed status by industry sector compared to species introduced (from Virtue *et al*. 2004).

Weeds via accidental introduction or produce contamination

Another serious source of weed entry is by accidental introduction or through produce contamination (Figure 1). The Australian Quarantine and Inspection Service (AQIS) employs 3300 staff that screen 150 million mail items, 11.9 million air passengers, 1.8 million cargo containers and 13 000 international vessels each year. Approximately 45 000 items are seized at airports each month and 25% of these are undeclared (AQIS 2008). These numbers are huge and with our global economy it's inevitable that weeds and weed seeds will enter via human transport or contaminated seed / grain or other produce shipments. Sixty one percent of plants introduced into Australia by accidental importation (640 species) have become weeds (Virtue *et al.* 2004, Figure 1). This form of entry results in by far the highest proportion of weed species development. This is logical as weedy species are generally very well adapted for dispersal via animals, machinery, soil and so on. Be it weed seeds clinging to a person's socks, or seed contamination in a 10 ton container of imported grain, this threat is particularly serious. Such data highlight the importance of border security and the need for special attention to agricultural produce shipments.

e-Commerce

Another serious issue for weed spread is the internet. The internet is undoubtedly a wonderful resource but the potential it has for increasing the introduction of a new weed species is unnerving. Mail ordering from internet catalogues has become increasingly popular over recent years as internet trade has expanded. The size of the e-commerce plant and seed industry is very hard to quantify due to its global nature, but a quick search showed 15 million 'mail order plants' global web sites, and 5 million 'mail order seeds' global web sites (King 2005). It has been estimated that e-commerce accounts for 0.8% of

the total Australian retail greenlife market in June 2004 (King 2005). Attempts have been made in America to reduce the retail trade of weed weedy species through e-commerce by developing a voluntary 'do not sell list'. This has proven to be a failure because the dealers resented being told what they could sell and those who failed to comply with the program could gain an economic advantage over those that did (Caton 2005). An alternative approach involving an internet surveillance tool, known as the Agricultural Internet Monitoring System (AIMS) has been developed and implemented in the USA and is proving to be effective in identifying, monitoring, and engaging with web sites and on-line traders listing declared noxious weeds. The tool is readily customizable for use in Australia and other countries and has been recommended for adoption, but to date this has not occurred (King 2005).

Case study: Mexican feather grass (*Nassella tenuissima*)

Exotic stipoid grasses are causing severe impacts to Australia's agriculture and environment (McLaren *et al.* 1998). For example, serrated tussock (*Nassella trichotoma*) is a Weed of National Significance costing NSW more than $40 million annually in lost production and control costs alone (Jones and Vere 1998). Its rate of spread can be seen in Victoria where a 4 ha infestation had become 30 000 ha by 1980 and 130 000 ha by 1998. A closely related species very similar to serrated tussock, Mexican feather grass, (*Nassella tenuissima*), has also become an issue in Australia as it is a popular ornamental grass species in the international gardening media and its seed is readily available by mail order via the internet (Blood 2006). In its counties of origin, Mexican feather grass is considered a more serious weed than serrated tussock (McLaren *et al.* 1998). During the 1990s, native grasses became very popular as ornamental plantings in Australia. In Melbourne, native grasses such as Poa tussock, (*Poa labillardierei*) were being used extensively as a low maintenance, attractive groundcover along road and freeway verges. The popularity of grasses in urban areas has resulted in rare plant nurseries taking an increased interest in importing new, attractive, hardy, easily grown species. Mexican feather grass was first reported being sold at a Sydney nursery in 1996, under the name 'Elegant Spear Grass' (known to botanists as *Austrostipa elegantissima*) which is an Australian native grass (Dellow personal communication) but was subsequently correctly identified (Jacobs *et al.* 1998). Similarly, in 1998, a landscape gardener identified a plant resembling serrated tussock at a rare plant nursery at Mount Macedon (57 km north west of Melbourne) being sold as *Stipa tenuissima*. He alerted authorities via the computer email network 'Enviroweeds' that links people interested in environmental weed issues around Australia and the world. This set in train an investigation that led to the removal and destruction of stock of these plants from twelve Victorian nurseries and a review of AQIS import regulations (McLaren *et al.* 1999). There is some irony in this case, since the species was ordered over the internet and the weed alert for its occurrence at the Mt Macedon nursery was also over the internet. This case was a precursor to the now very effective weed spotter network initiated by Kate Blood in Victoria and now also being utilized in Queensland. An additional 13 nursery retailers were identified selling *N. tenuissima* under the name 'Stipa tenuissima-Ponytails' across Melbourne during 2000. Unfortunately, at least 23 of the 116 *N. tenuissima* plants available for sale had already been sold. An additional 400 *N. tenuissima* were destroyed from the wholesaler distributing them to the nurseries (McLaren 2000). The Weed CRC in collaboration with the Victorian Department of Primary Industries conducted a media campaign in local papers and radio seeking the return of the purchased 'weeds'. The CRC for Australian Weed Management offered a reward of a $20 nursery voucher to any people who could return the plants within a month. This resulted in a truckload of Mexican feather grass being removed from sale from a wholesale nursery with the full co-operation of the grower concerned. The surrender of these plants may have potentially saved Australia $39 million over the next 60 years (CRC for Weed Management Systems 2001). The latest report is that Mexican feather grass has been recently found for the first time in Australia at a National Park at Namadgi in the ACT (Steve Taylor, Enviroweeds). The Mexican feather grass case highlighted an important anomaly in the plant import appraisal process and prompted Biosecurity Australia to fully implement the permitted list system to the species level which occurred in 2006.

Case study: Brown top bent grass (*Agrostis castellana*)

Creeping bent grass, *Agrostis stolonifera* is a commonly used turfgrass for golf courses. A closely related bent grass, *Agrostis castellana,* has become one of the most significant perennial grass weed species affecting high rainfall pasture production in central Victoria (Hill *et al.* 1996). There has been considerable uncertainty that the traditional identification of bent grass in Victoria was *A. capillaris* but this has since been confirmed as *Agrostis castellana* (Bateson 1998). Bent grass conservatively costs Victoria $30–40 million per year in control costs and lost production (Hill 1994) and is also an important weed in Tasmania, where it reportedly costs farmers $21 million per year (R. Hill personal communication). In Victoria, *A. castellana* can be managed through strategic application of low rates of glyphosate to prevent seed head production, making the grass palatable over summer (Hill *et al.* 1996). It has been estimated that spraytopping bentgrass using glyphosate is saving Victorian farmers approximately $10 million per year (R. Hill personal communication).

Glyphosate-resistant creeping bentgrass (GRCB) (*Agrostis stolonifera*) has been developed by a USA company, The Scotts Company, Marysville, Ohio, and is proposed for commercialization and use on golf courses in the USA. The introduction of glyphosate-resistant creeping bentgrass has been advocated to improve the ability of golf course curators to control weeds on fairways, tee boxes and greens (Banks *et al.* 2004). The US Department of Agriculture (USDA) is running its first full environmental impact assessment of a genetically modified (GM) plant after GMCM escaped into the wild in the US before securing USDA approval (Coghlan 2006). Bentgrass is a perennial, so once established it grows year after year and reproduces, whereas most GM crops – including, soybeans, cotton, maize and canola are annuals that are harvested each year and replaced with an entirely new crop (Coghlan 2006). Multiple lines of evidence from greenhouse and laboratory tests document movement of GRCB pollen on a landscape level that encompassed 310 km^2 (Watrud *et al.* 2004). In 2006, three years after the transgene source fields were taken out of production and a mitigation programme was initiated, 62% of the 585 creeping bentgrass plants tested in situ were glyphosate resistant. It is unrealistic to think that containment or eradication of GRCB could be accomplished (Zapiola *et al.* 2008). Field studies have shown that *Agrostis stolonifera* can hybridize between other *Agrostis* species and closely related *Polypogon* spp. (Belanger *et al.* 2003). Interspecific hybrids have been recovered between GRCB and *A. capillaris* and *A. castellana* at frequencies of 0.044 and 0.0015%, respectively, considerably lower than intraspecific transgenic progeny recovery in the same experimental plots (0.631%). No interspecific hybrids were recovered with *A. gigantea* or *A. canina* (Belanger *et al.* 2003). The fact that GRCB can hybridize with other *Agrostis* spp. and form transgenic progeny suggests that the introduction of GRCB to Australia could potentially lead to development of transgenic glyphosate resistant *A. castellana* in Australia. Such a development would be a disaster for Australian farmers and should prompt governments and weed scientists to require stricter due diligence and risk assessments before undertaking such GM research.

Conclusion

There is little doubt that Australia should be proud of its efforts in the areas of quarantine, weed management and weed research. Comparisons to the efforts of other nations only enforce this. The message that is also strong though, is that the weed war is far from over in this country. The hard work already put into this problem has given Australia the ideal mechanisms by which to significantly reduce further weed entry into the country. Economics govern the continued success of weed management and unfortunately financial commitment to the problem and education is not as it should be. The many successes and advances made by the CRC for Australian Weed Management in linking and co-ordinating weed research programs across Australia has been impressive. Biosecurity Australia's implementation of the permitted list system to the species level is a significant advance in prevention of new weed incursions into Australia. However, we still have the serious issue of how to deal with the 25–30 thousand exotic plant species already introduced into Australia. A wish list of processes to deal with these issues are listed below and support such suggestions previously made by Andreas Glanznig (Glanznig 2005ab, 2006).

Put in place an ongoing funded Weed CRC to oversee and implement National weed programs listed below:

- Implement a comprehensive permitted list/weed risk assessment system at both a National and State level.
- Implement National weed list legislation so that any weed listed noxious weed in one State or Territory can't be sold or traded in another.
- Implement a National Weed Spotter program that is now working very effectively in Victoria and Queensland.
- Implement National plant labelling systems so that the Horticulture and Agricultural industries can be more closely regulated with regard to invasive plants.
- Phase out supply and trade of high risk invasive plants nationally and supply and promote suggestions for alternative less invasive species.
- Place much stricter National control on imports likely to contain invasive species contaminants.
- Implement a National weed mapping system so that authorities can respond unilaterally to weed threats.

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Agricultural introductions as a source of weeds: what have we missed?

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Introduction

Grice (2008) raised the issue of commercial weeds: those plants that have a real or perceived commercial value but which also impose a cost through their invasive potential. In this paper, I argue that, although it is recognized that most naturalized plants in Australia were deliberate introductions, there is widespread ignorance about the perceptions of commercial value that lead to their introduction. Such ignorance is likely to lead to insufficient weighting being given to the threats posed by trials of potential new crop and pasture species and varieties. In this paper, I provide case studies of several taxa for which good records exist of their introduction for potential commercial agricultural production, but for which recent literature appears ignorant of the history of their perceived value and deliberate introductions.

Recent weeds literature has focused on the potential for ornamental plants to become weeds because the gardening industry is has been the source for the introduction of 25 360 or 94% of new plant species into Australia (Randall 2001, Mack and Erneberg 2002, Groves *et al*. 2005). However, as shown by Cook and Dias (2006) many of the so-called garden plants, and especially those in the families Poaceae (grasses) and Fabaceae (legumes), were also introduced by agriculturalists for various purposes. For grasses and legumes, the approximately 2200 species in each family that were introduced under the Commonwealth Plant Introduction (CPI) scheme comprised nearly twice as many species in those families as occur naturally on the whole continent. Of the grass species introduced under CPI, about 10% are naturalized, although sources other than the CPI scheme may have contributed to the extant populations.

In this paper, I provide case studies for five genera containing plants that are either noxious weeds or Weeds of National Significance: *Eragrostis*, *Mimosa*, *Nassella*, *Sporobolus* and *Parkinsonia*. I show how contemporary weeds literature has overlooked evidence that their utility for forage or soil conservation was viewed favourably in the past and that agriculturalists were responsible for at least some of the material that has been naturalized. I do this not to attribute blame but as a basis for arguing that a sound understanding of the origin of weedy species is critical to the development and implementation of policy and plans for their control.

Case studies

Eragrostis

Eragrostis curvula is one of about 54 species of *Eragrostis* introduced to Australia under the Commonwealth Plant Introduction scheme as a potential pasture grass. Due to the low palatability of many of its strains, this species is now a declared noxious weed in Western Australia, South Australia, Victoria, New South Wales and Tasmania. Parsons and Cuthbertson (1992) describe it as having been 'imported for experimental assessment several times since' 1900. In their 2001 revision (Parsons and Cuthbertson 2001), they describe the origin as:

'this grass was probably first introduced to Australia by accident as a contaminant of pasture seed. Different cultivars of this grass have also been used as a soil stabilizer in erosion control situations.'

These descriptions completely fail to capture the extent of the effort to trial and promote this species. In fact, 164 accessions were deliberately introduced, and one line, 'Consol' is a registered herbage plant cultivar (Anon 1982). Between 1910 and 1966 trials were conducted at 24 sites across Australia (Leigh and Davidson 1968). A paper proposing to continue evaluating *E. curvula* for soil conservation purposes in New South Wales was published just after the plant was declared a noxious weed in several shires of that state (Johnston and Aveyard 1977). The registration of cultivar Consol in 1982 mentioned that the unacceptability to livestock of some naturalized forms of the species was causing some concern, but did not state that the species was declared noxious in certain areas five years earlier (Anon 1982). An authoritative review of *E. curvula* published in 1990 by the Food and Agriculture Organization of the United Nations and co-authored by Queensland pasture agronomist P.J. Skerman made no mention of its noxious weed status but rather concluded that the grass 'establishes easily, persists well under grazing…, [is] valuable in erosion control [and has] good palatability' (Skerman and Riveros 1990). A recently published list of the strengths and weaknesses of this species in an interactive CD on forages (Cook