The impact of pampas grasses as weeds in southern Australia

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Summary

Three species of *Cortaderia*: *C. jubata*, *C. richardii* and *C. selloana* (pampas grasses) are naturalized in Australia. All are colonizing plants and have a high potential to become significant weeds of bushland, forests, roadsides and waste areas in southern Australia. As weeds, these grasses compete with desirable plants, increase fire hazards and the costs of forestry operations and reduce conservation values and access.

Identification of *Cortaderia* spp. may be difficult and a key based on vegetative and reproductive characters is provided. *Cortaderia* spp. can be controlled by mechanical or chemical methods or by grazing. All species have become firmly established in Tasmania. The operation and success of a recent State Government administered control program are described. The potential of *Cortaderia* spp. to become serious weeds suggests that eradication or containment programs should be initiated in mainland States.

Introduction

The genus *Cortaderia* Stapf. (Poaceae) contains 24 species world-wide – 19 native to South America, four to New Zealand and one to New Guinea (Morris 1991).

The term 'pampas grass' should be applied only to *Cortaderia* spp. originating in South America. However, the term is commonly applied to all three species of *Cortaderia* known to be naturalized in Australia of which two originate in South America (*C. jubata* (Lem.) Stapf. and *C. selloana* (Schult. et Schult.f.) Asch. et Graeb.) and one in New Zealand (*C. richardii* (Endl.) Zotov). In this paper the latter interpretation will be used.

Until recently, pampas grasses have been regarded as desirable plants in Australia. Plantings for windbreaks, soil stabilization, forage and ornamental purposes have been common during the last twenty years. The weed status of these grasses in Australia has now been formally recognized since 1985.

Although *Cortaderia* spp. were not listed as weeds by Holm *et al.* (1979), the propensity of the South American species to invade forests has been recognized in New Zealand since the early 1970s (Knowles and Ecroyd 1985). In addition, *C. jubata* has been recognized as a weed in South Africa (Knowles and Ecroyd 1985) and of disturbed coastal areas in California (Costello 1986).

In Australia, *Cortaderia* spp. are regarded as weeds of bush and recreation land, forests, roadsides, and waste areas. They are not generally agricultural weeds.This paper describes the current and potential impact of pampas grasses as weeds in Australia with particular emphasis on their status as environmental weeds.

Distribution of *Cortaderia* spp. in Australia

Three species of *Cortaderia* are recorded as naturalized in Australia: *C. selloana* (common pampas grass), *C. jubata* (pink pampas grass) and *C. richardii* (toetoe). The first species has been widely planted for windbreaks and ornamental purposes.

Naturalized plants of the three species are most common in Tasmania. *C. selloana* and *C. jubata* are widespread throughout the settled areas of the State. *C. richardii* is restricted to the West Coast (west of Derwent Bridge), although limited ornamental plantings have been made in other areas. *C. selloana* and *C. jubata* have been observed as weeds of bushland, forestry plantations, ornamental plantings, roadsides and waste areas. *C. richardii* has only occurred as a weed of bushland and roadsides in high-rainfall areas.

In mainland Australia, *C. selloana* is naturalized in Victoria, New South Wales, South Australia and Western Australia. In New South Wales, it has been reported as invading disturbed urban bushland on the Central Coast (Hall and Dellow 1987). In Victoria, *C. selloana* is widespread on public and private land and occurs in several National, State and Coastal Parks (Williamson 1991). In a 1991 survey of environmental weeds, *C. selloana* was reported as an 'important environmental weed' in nine of the sixteen Department of Conservation and Environment Regions in Victoria (McKenzie 1991) but the current infestation level was considered 'light' (Williamson 1991).

In the mainland States, *C. jubata* has been reported from Victoria only. However, this recent record (1990) may reflect difficulties in distinguishing *C. jubata* from *C. selloana* rather than the previous absence of the former species. A similar situation may prevail in other States. *C. richardii* has not been reported as naturalized in any mainland State.

C. selloana is native to Argentina, Brazil, Chile and Uruguay and *C. jubata* to Argentina, Bolivia, Ecuador and Peru (Connor and Edgar 1974, Knowles and Ecroyd 1985). Nicora (1978) and Cabrera and Zardini (1978) note that *C. selloana* is most common on moist, sandy soils on grassy plains and slopes. These native habitats are approximately between latitudes 25°S and 40°S, the same range over which pampas grass is most abundant in New Zealand (Knowles and Ecroyd 1985) and which covers a major proportion of mainland Australia, from southern Queensland to Bass Strait.

Given the observed vigour of naturalized pampas grass in a wide range of habitats in Tasmania, it is evident that the potential distribution of these grasses in southern Australia is only limited by moisture availability and, to a lesser extent, altitude.

Significance of *Cortaderia* spp.

Cortaderia spp. have their greatest impact on forestry operations and in conservation areas. In forest plantations, pampas grass may compete with seedling trees, especially softwood species, reducing establishment and retarding growth. In older forests, pampas grass increases the fire hazard and impedes access for silviculture.

Only *C. jubata* and *C. selloana* have been reported as weeds of commercial forests in Australia. Similarly, in New Zealand, the native *Cortaderia* species occur only rarely as significant forestry weeds (Knowles and Ecroyd 1985).

Pampas grasses have been estimated to increase silvicultural tending costs by 144% in New Zealand, with control treatments which barely ensured tree survival costing $NZ350 per hectare in 1983 (Gadcil *et al.* 1984).

Quantitative estimates of the potential costs of pampas grasses to Australian forestry industries have not been published. However, in 1987, the Tasmanian Interdepartmental Pampas Grass Committee estimated the potential cost of pampas grass control in the establishment of *Pinus radiata* and eucalypt plantations to be $400/ha. This would add $1.4 million per annum to the cost of plantation establishment in the State.

In conservation areas, pampas grasses compete with native vegetation, reduce conservation and aesthetic values, reduce recreational access on tracks and increase the fire hazard.

Pampas grasses also establish readily on roadsides, quarry sites, waste areas and riverbanks, causing similar problems to those listed above, as well as increasing the cost of vegetation management.

The financial loss due to pampas grass infestation in bushland and similar habitats is extremely difficult to measure. The contingent valuation method has been used in New Zealand to assess the value to the community of preserving bushland threatened by the environmental weed *Clematis vitalba* L. (Greer and Sheppard 1990). A cost of $NZ18.36 to $NZ46.37 per head of

adult population was reported as the extra annual tax that New Zealanders would agree to pay to finance research into *C. vitalba* control.

Limited evidence suggests that Australians would react similarly towards a significant environmental weed such as pampas grass. Those respondents to an invitation for submissions on the formulation of a management strategy for the World Heritage Area in south-west Tasmania who specifically addressed the issue of introduced plants, were unanimously in favour of eradication of such plants (Anon. 1990). One of the most conspicuous introduced plants in the area is *C. richardii*.

The high level of community concern about the environmental effects of *C. richardii* and *C. selloana* is further demonstrated by the observed success of voluntary control programs against these weeds in Tasmania.

Pampas grass infestations on roadsides and waste areas are usually controlled by application of glyphosate. Herbicide cost varies from $65 per hectare for seedlings to $260 per hectare for established plants (Harradine, unpublished data). Labour and equipment costs for application may far exceed these herbicide costs in many areas where access is difficult.

Cortaderia spp. are not generally considered weeds of agricultural significance as plants are readily grazed by stock, especially cattle, and have shown no propensity to become weeds in cropping areas. In New Zealand and parts of Tasmania, *Cortaderia* spp. have been extensively planted for shelter and stock fodder in pastoral situations (Gadcil *et al.* 1984, Duckett 1989).

Identification of *Cortaderia* spp. in Australia

All species of *Cortaderia* occurring in Australia are large tussock-forming perennials; have mainly basal, flat, long, linear leaves with a ligule of hairs; produce flowers in large plume-like panicles on stout, unbranched culms; and are dioecious or gynodioecious.

C. richardii is readily distinguished from the South American species both in the vegetative and reproductive stages (Table 1). This species is gynodioecious (separate hermaphrodite and female plants) and apart from the development of anthers, the female and hermaphrodite spikelets and plants are identical (Morris 1991). In female plants, anthers are formed but fail to develop.

'Typical' specimens of *C. jubata* and *C. selloana* are easily distinguished (Table 1). However, in Tasmania, some specimens of female *C. selloana* appear to differ from *C. jubata* only in their flowering times. In these specimens, all other key features are shared by both species.

Hybridization between *Cortaderia* spp. has been reported (Connor 1965a, 1983, Knowles and Ecroyd 1985) although apomictic reproduction in *C. jubata* (c.f. *C. selloana*) would mitigate against hybrids of other species. This suggests that *C. jubata* plants are likely to be less morphologically variable than *C. selloana*. Thus, most if not all of these 'non-typical' plants are best assigned to *C. selloana*. Availability of distinct cultivars of *C. selloana* in New Zealand for ornamental and agricultural purposes (Chapman 1968, Knowles and Ecroyd 1985) indicates high genetic variability in this species.

C. jubata plants are always female and apomictic (Connor 1965a in which *C. atacamensis* (Phillipi) Pilger = *C. jubata*; Morris 1991). Inflorescences of all *C. jubata* found in Tasmania have appeared purple to pink from the colour of the nerves on the lemma and palea. Inflorescences fade to straw-coloured as the seeds mature.

C. selloana is gynodioecious. In naturalized populations in New Zealand, female and hermaphrodite plants occurred in a ratio of 1:1 (Connor 1965a) but no data on the sex ratio of Australian populations is available. Female flowers are similar to those of *C. jubata* with large, exerted stigmas and anthers reduced to staminodes. However, unlike those of the latter species, female flowers of *C. selloana* are not apomictic, requiring pollination from hermaphrodite plants before seed is formed. Hermaphrodite plants of *C. selloana* have smaller ovaries and styles than female plants. Seed produced by hermaphrodites is also smaller (Connor 1965a, 1965b). Under experimental conditions, the proportion of florets producing seed in female plants (about 99%) was more than twice that in hermaphrodites (47%) (Knowles and Ecroyd 1985). In addition, female plants have more florets per spikelet (Connor 1974). The seed germination rate of female plants was eight times that of hermaphrodites (Knowles and Ecroyd 1985).

Lemmas from female plants of *Cortaderia* spp. are densely hairy at the base with scattered hairs above, while lemmas from hermaphrodite plants are glabrous except for a few silky hairs above the callus (Morris 1991). These lemma hairs not only give the inflorescence of the female plant a 'fluffy' appearance (c.f. the hermaphrodite inflorescence) but also aid wind dispersal of the seed (Knowles and Ecroyd 1985).

These differences between the female and hermaphrodite plants indicate that most seed is produced by, and dispersed from, the female plant while the hermaphrodite acts principally as a source of pollen.

Table 1. Key to *Cortaderia* spp. naturalized in Australia.

1. Leaf base with white waxy surface. Leafblade with distinct secondary veins between midrib and edge of leaf. Midrib continued to leaf base. Dead leaf ends not spiralled. Flowering time October to January. Culms slender, more or less nodding. Panicle light brown to golden. Spikelets 2-3 flowered.

   C. richardii

   Leaf base without white waxy surface. Leafblade without distinct secondary veins between midrib and edge of leaf. Midrib not continued to leaf base. Dead leaf ends may hang down and form a spiral. Flowering time mid-summer to autumn. Culms stout, more or less erect. Panicle white, light brown or purple-pink. Spikelets 4-6 flowered.

   2

2. Leaf blades flat, bright green, drooping from the sheath usually with many leaf tips touching the ground. Flowering time late January to March. Panicles purple-pink, usually well exerted beyond the leaves. Plants female only. Ovary enlarged at anthesis. Lemmas densely silky hairy at base and on margins.

   C. jubata

   Leaf blades more or less folded at the base, dull- to blue-green, high arching usually with few tips touching the ground. Flowering time mid-March to late May. Panicles white, light brown or purple-pink, only slightly exerted above the leaves. Plants female or hermaphrodite. Ovary not enlarged at beginning of anthesis. Lemmas of female plants densely silky hairy at base and on margins; lemmas of hermaphrodite plants glabrous except for a few silky hairs above the callus.

   C. selloana

Ecological characteristics of *Cortaderia* species

The pampas grasses present in Australia are colonizers of disturbed areas. All species produce florets covered in long hairs and thus are equipped for wind dispersal. McKinnon (1984) reported seed of South American *Cortaderia* spp. being dispersed over 30 km in New Zealand. Other authors suggest that dispersal up to 25 km is common (Knowles and Ecroyd 1985, Duckett 1989). Yields of up to 100,000 seeds per inflorescence have been reported for *C. selloana* (Duckett 1989).

Common sites of infestation of *Cortaderia* spp. are roadsides, road cuttings, quarry faces, sand dunes, mine spoil, new forest plantations and burned or disturbed bushland (e.g., Connor 1965a, Knowles and Ecroyd 1985, Duckett 1989, Harradine personal observation). Seedlings, espe-

cially those of *C. jubata* and *C. selloana*, do not appear to compete well with other vegetation and the most vigorous and rapid establishment occurs on sites devoid or almost devoid, of other plants. This preference for open habitats may reflect the open pampas origins of these species.

Gadcil *et al.* (1984) suggested that the pampas grass problem in New Zealand forests was being accentuated by the trend towards more open forest with fewer trees per hectare and more emphasis on pruning and thinning.

C. richardii appears to be more competitive than *C jubata* and *C. selloana* in Tasmania, as it has been observed to colonize areas with only slight disturbance, e.g., on river banks or as a result of low intensity fires (Duckett 1989). *C. richardii* is also more tolerant of shade and waterlogged soils but appears to be less tolerant of moisture stress. On Tasmania's west coast, *C. richardii* grows vigorously in swamplands and moorlands subjected to inundation to several centimetres above the soil surface for at least part of the year (Harradine, personal observation).

Although *C. selloana* is most common on sandy soils in its native habitat (Cabrera and Zardini 1978), soil texture does not appear to limit *Cortaderia* ingress elsewhere. In recommending its use for agricultural purposes, Chapman (1968) noted that a light soil with a clay sub-soil is best for *C. selloana* growth, although it will grow satisfactorily on heavier soils. Naturalized plants may occur on deep sands to heavy clays, including shallow, gravelly soils on quarry faces and mine spoils (Connor 1965a, Gadcil *et al.* 1984, Harradine personal observation). Jacques (1957) calculated that the roots of a single plant of *C. selloana* could effectively occupy a soil volume of about 103 m^3 with a lateral root spread of 4 m and a rooting depth of over 3.5 m, allowing it to grow on poor soils and withstand drought.

Hall and Dellow (1987) concluded that 'pampas grass appears to have no special habitat preference; it can be found growing in virtually all vegetation associations'.

The Tasmanian *Cortaderia* control program

The female form of *C. selloana* was introduced to Tasmania in the early 1880s (Duckett 1989). Although seed of particular strains of this species was imported into Victoria and possibly Tasmania in the early 1940s (Chapman 1968), plants for windbreaks, stock shelter and ornamental plantings were propagated vegetatively, at least until the late 1970s.

As the demand for pampas grass plants in agriculture and horticulture rose dramatically in the late 1970s and early 1980s, seed from New Zealand was imported into Tasmania to increase the speed of propagation (Duckett 1989). It is generally thought that both *C. jubata* and fertile forms of *C. selloana* were accidently imported with this seed. Alternatively, *C. jubata* may have been imported deliberately as a pink-flowered form of *C. selloana* for ornamental use.

Both female and hermaphrodite types of *C. selloana* were present in Tasmania before the introduction of seed from New Zealand (Townrow 1969). However, there is no record of concern by local foresters or weeds researchers about the appearance of volunteer *C. selloana* plants until the mid-eighties. This suggests that the early types of *C. selloana* were probably of very low fertility. Further, the commercial production of seed of *C. selloana* would have selected for highly fertile types. These types would then have been imported into Tasmania and other areas where propagation from seed was being undertaken. This explanation is supported by the presence of many large, very old *C. selloana* plants in the State which have shown no propensity to produce seed and spread despite the recent availability of pollen sources.

The weed potential of *Cortaderia* spp. in Australia was first 'officially' raised by the Australian Weeds Committee in 1985. At that time, *C. selloana* was noted to be naturalized in New South Wales and to a very limited extent in Tasmania, while *C. jubata* had not been recorded in Australia.

In 1986, Hall (1986) reported that small infestations of *C. selloana* in forests in NSW, ACT and Victoria had been the subject of eradication programs. At this time it was also recognized that Tasmania was the main area where *C. selloana* was used for agricultural purposes, with most plants being grown from seed imported from New Zealand. Such seed imports were considered to pose a high risk of accidentally introducing *C. jubata*. However, it was noted that 'there is, however, a strong feeling in Tasmania that climatic conditions in that state will prevent Cortaderia (*sic.*) from becoming a weed' (*ibid.*). *C. jubata* was first identified in Tasmania in 1987 (Tasmanian Herbarium records) and within twelve months of this initial identification, it was located at 70 sites throughout the State..

The weed potential of *C. richardii* had been recognized much earlier. The then Department of Agriculture had conducted herbicide trials on roadside plants of this species from early 1984 (Harradine, unpublished data).

In response to the perceived extreme threat to forestry operations and conservation areas in Tasmania, an Interdepartmental Pampas Grass Working Party was established in June 1987 to formulate strategies for pampas grass control.

The following recommendations of this working party were implemented (adapted from Duckett 1989):

1. All Cortaderia spp. were declared Secondary and Prohibited Weeds under the Noxious Weeds Act 1964.

The initial proposal from the forestry industry was to declare all *Cortaderia* species 'Noxious Weeds' under the Noxious Weeds Act. By definition under the Act, this would have required the immediate control, with the aim of eradication, of all *Cortaderia* plants in the State, regardless of their agricultural or weed significance. The large number of plants in the State would have made such a proposal impossible to administer with the personnel available. Previous experience with other weeds has shown that such a situation can have negative effects due to the forced inconsistency in the application of legislative powers. In addition, the required immediate removal of pampas grass windbreaks and fodder plantings would have led to an outcry from sections of the farming community.

Difficulties in positively distinguishing *C. jubata* and *C. selloana* in the field would have led to legislative problems in enforcing control had each *Cortaderia* species been listed separately. Under the Noxious Weeds Act, Weeds Inspectors are required to specify the target weed on enforcement notices and other documents, by its correct botanical name.

***Cortaderia richardii* (left) and *C. selloana* (right)**

As 'Secondary Weeds', *Cortaderia* infestations could be dealt with at the discretion of Weeds Inspectors so that control efforts could be concentrated on the most significant infestations. In addition, where innocuous forms of pampas grass were present in ornamental plantings and windbreaks, control did not have to be enforced (c.f. a 'Noxious Weed').

As 'Prohibited Weeds', importation of *Cortaderia* spp. into the State and movement within the State were prohibited. This provision also prevented the propagation and sale of *Cortaderia* spp. Local nursery industry representatives were consulted before the declaration and did not object to the proposal.

2. Priorities for pampas grass removal were assigned to different land-use areas.
Within State forests and National Parks the aims were to eradicate and maintain total exclusion of all *Cortaderia* spp. This latter aim required the enforced control of pampas grass on private land adjacent to State reserves where it posed a threat.

On all other Crown Land and Government controlled land such as road easements and riparian reserves, pampas grass was to be removed wherever feasible, especially where plants may have served as pollen or seed sources.

On rural properties, especially where pampas grass removal would cause significant financial losses, removal was encouraged by the use of assistance packages. For qualifying landholders, the Forestry Commission advised on suitable replacement species and provided discounts for their purchase.

In urban areas, control was not enforced unless the particular plants were observed to pose a threat to adjacent land or the local government authority concerned decided to implement an eradication scheme. The publicity campaign described below resulted in the voluntary removal of most pampas grass plants in urban ornamental plantings.

In all cases, where flowering plants could not be dealt with immediately, flowering stems were removed and destroyed. The parent plants were then treated at a later time.

3. A publicity campaign utilizing print, radio and television media was initiated.
Two publications were produced with funding from the Forestry Industries Association of Tasmania, herbicide manufacturers and the State Government. Fifty-three thousand copies of a small, general information pamphlet were distributed widely through plant nurseries, local councils, Government agencies and organizations involved in bushland conservation. In addition, three thousand copies of a technical brochure were distributed to appropriate companies and organizations.

The novelty value of the story regarding the sudden change of status of pampas grass from a commercially sold plant to a 'noxious weed' attracted wide coverage by the media. This was of great significance in initiating the voluntary removal of pampas grass on private land. The publicity also favourably coincided with increasing community interest in 'environmental weeds'. Seminars on the pampas grass problem were provided for local and State Government agencies and interested organizations.

4. Voluntary labour from community organizations was enlisted for the removal of pampas grass from bushland.
In most cases, the volunteers were supervised by experienced personnel from the Forestry Commission or the Department of Parks, Wildlife and Heritage. In one major exercise, 6,000 plants of *C. richardii* were removed by bushwalkers and other volunteers from the World Heritage Area and surrounding areas.

5. A State Co-ordinator for the pampas grass control program was appointed to oversee the implementation of the Pampas Grass Working Party recommendations.
Such a position was existent between 1987 and 1990. It was jointly funded by several Government Departments and located within the Forestry Commission.

The success of the Tasmanian program

Within two years of the commencement of the pampas grass control program, many thousands of pampas grass plants had been removed or treated with herbicide. All plants found near or in conservation and forestry areas had been controlled and ornamental plantings on roads and around Government buildings were removed. In addition, many plants had been voluntarily removed from private gardens and rural land and most local government authorities were undertaking control on land under their jurisdiction (Duckett 1989).

Despite this high level of initial success, pampas grass plants are still widely distributed throughout the State, principally as ornamental plantings in home gardens and as windbreaks in rural areas. In addition, the recent establishment of seedlings has been observed both in areas where mature plants had been controlled and, to a far lesser extent, in new areas.

The publicity campaign to encourage voluntary removal of plants is continuing. In addition, spot treatment of isolated plants by weeds inspectors, and enforced control of larger infestations by landowners are being undertaken to control *C. jubata* and any plants of *C. selloana* which show a propensity to spread. For the longer term, resources are being directed at the eradication of *C. jubata*, *C. richardii* and all pink-flowering forms of *C. selloana* (to avoid confusion with *C. jubata*).

Future options for the campaign are:
a) Eradication of all *Cortaderia* spp.
b) Eradication of all *Cortaderia* spp. except for white-flowered, female plants of *C. selloana* (this would enable ornamental, windbreak, soil stabilization and stock fodder uses of pampas grass to continue without the threat of spread as no pollen source would be available).
c) Control of all *Cortaderia* plants where they threaten adjacent forestry or conservation areas or where they show a propensity to spread.

These options are listed in decreasing order of resource requirements. The option chosen will depend principally on the future resource availability for the campaign. The above options are also relevant for other States considering action against *Cortaderia* spp.

Control methods for *Cortaderia* spp.

Mechanical control
Mechanical removal is often the most appropriate control method in urban and bushland areas, especially for small plants. However, in bushland, site disturbance must be minimized to prevent re-invasion.

Hand-grubbing of small plants and the use of an excavator or backhoe for the removal of large plants has been highly effective for all *Cortaderia* spp. in Tasmania (Duckett 1989, Harradine personal observation). For large plants, removal of topgrowth by brushcutter or burning will facilitate access to the crown and roots for grubbing.

While complete removal of the roots has been recommended to prevent regrowth (Hall and Dellow 1987), Tasmanian experience indicates that once the crown and top section of the roots have been removed, regrowth from the remaining roots is unlikely.

Grubbed plants should be removed from bushland areas and destroyed. Plants left lying on the surface may take root and re-establish if the soil is moist (Hall and Dellow 1987).

Inflorescences should be cut from plants and bagged for later destruction to prevent seed dispersal during mechanical operations.

Chemical control
Trials have been conducted in New Zealand and California to determine suitable herbicides for control of *C. selloana* and *C. jubata* (e.g., Costello 1986, Saville *et al.* 1986, Davenhill 1988). Effective herbicides are clethodim, glyphosate, haloxyfop, hexazinone and imazapyr.

Local experience indicates that glyphosate and hexazinone are effective for control of the above species in Tasmania (Duckett

1989). Other herbicides have not been extensively tested.

Glyphosate has been widely used in Tasmania for the control of both seedlings and mature plants. A rate of 7.2 g a.i. L^{-1} (i.e. 20 mL of 360 g L^{-1} formulation per litre) by high volume application equipment or 1 part 360 g L^{-1} formulation to 2 parts water by wiper equipment applied when the grass is actively growing is recommended (Duckett and Wilkinson 1988). The high volume rate may be halved for treatment of seedlings and young plants (Harradine, unpublished data).

For large, established plants, the topgrowth may be removed by cutting or burning and the regrowth treated when about 20 cm high. This method reduces the amount of herbicide required and permits more precise application, thus reducing the risk of damage to non-target plants.

Hexazinone is a soil residual herbicide, which in high rainfall areas may be leached into the root zone of adjacent plants. For this reason, its use should be restricted to spot applications near tolerant species (e.g., in pine plantations) or in waste areas. This herbicide is best applied basally by spotgun at 3 – 4 mL of 250 g L^{-1} formulation per large plant (Duckett and Wilkinson 1988).

Glyphosate at the above rate is also effective for control of *C. richardii*, while flupropanate is not effective (Harradine, unpublished data). Bowers and Porter (1975, 1977) reported that *C. fulvida* (Buch.) Zotov (another New Zealand native species) is susceptible to hexazinone. This herbicide is likely to be effective on *C. richardii*, although its propensity to leach would limit its use in the high rainfall habitats typical of this species.

Glyphosate is currently the only herbicide registered in Australia for control of pampas grass.

Control by grazing

C. selloana and *C. jubata* are readily grazed by cattle (West *et al.* 1988) and grazing has been recommended for control of these species in commercial forests (New Zealand Forest Service 1985, Dale and Todd 1988).

Conclusion

Pampas grasses have a high potential to become serious weeds of bushland and commercial forests in southern Australia. This potential has already been demonstrated in Tasmania and New Zealand.

Fortunately, the weed potential of *Cortaderia* spp. has been recognized in other areas of Australia before significant spread has occurred. As control of established infestations is expensive and, in many situations, difficult, eradication or containment programs should be established in relevant areas while the problem is still manageable.

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