A system of assessing proposed plant introductions for weed potential

F.D. Panetta[A], Department of Agriculture, Baron-Hay Court, South Perth, WA 6151, Australia.
[A]Present address: Department of Lands, GPO Box 1401, Brisbane, Queensland 4001, Australia.

Summary

Many of Australia's most serious weeds have been introduced intentionally. Such introductions were made during times when there was little appreciation of the problems created for agriculture and the environment when plants spread beyond their points of introduction. Today there is a greater awareness of the risks associated with introducing plants to Australia. Owing to current legislative inadequacies, however, routine quarantine procedure can permit entry to species that are known to be weedy elsewhere in the world. An assessment system is presented which evaluates proposed plant introductions on the basis of their potential to become invasive in Australia. Primary considerations are whether taxa are weedy elsewhere and whether they possess noxious characteristics. The system can also be used to determine risk status classifications for contaminants of imported goods.

Introduction

The most effective way to manage the species that pose threats to either agricultural activities or the natural environment is to exclude them from Australia. It is probably inevitable that weeds will continue to find their way into Australia, however competent quarantine services might be (Groves 1986), but almost half of Australia's most harmful weeds are known to have been introduced intentionally (Figure 1), either as ornamentals or as species that demonstrated agronomic potential (Parsons 1981, Hazard 1988, Humphries *et al*. 1991, Parsons and Cuthbertson 1992). Such data parallel those of Kloot (1987), who found that 57% of the species in the naturalized flora of South Australia were introduced intentionally. Of these, 70% were introduced for ornamental purposes.

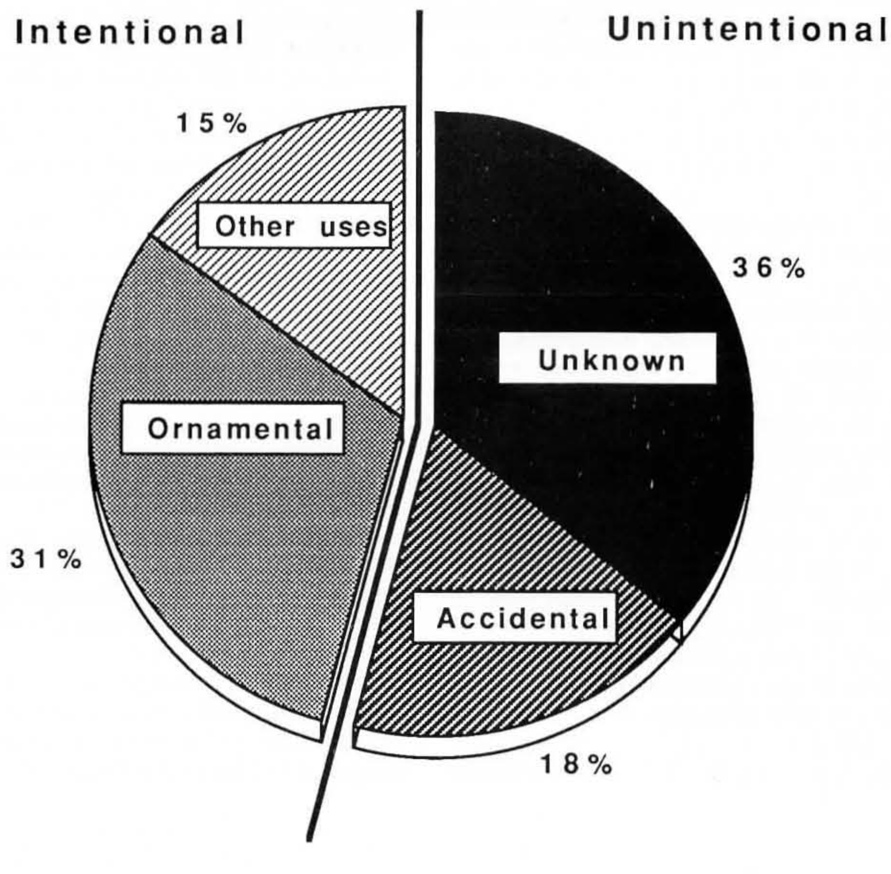
One hundred years ago, the knowledge of a plant's potential invasiveness may not have deterred people from introducing it (indeed they might have felt encouraged to do so). Today, the general awareness of the damage caused by weeds, in particular to the natural environment (Humphries *et al*. 1991), has engendered a will to prevent the ingress of potentially harmful species.

Federal legislation to prohibit the entry of weeds is embodied in the Quarantine Act 1908. Prohibited taxa are listed in two schedules of Quarantine Proclamation 86P: Schedule 1 contains 66 prohibited species (85% of which already occur in Australia) and Schedule 2 itemizes 19 prohibited genera. Clearly, there is a need for a procedure to assess the risks posed by importation of other plants, especially those that are of interest for horticultural, agronomic or reclamation works purposes. The procedure for assessing the risks associated with the introduction of another kind of organism, viz. a biological control agent, is well established (Delfosse and Cullen 1985).

The risks to which Australia is exposed in the absence of a similar procedure for plants are illustrated by a current problem. During 1990 a Western Australian company involved with the revegetation of salt-affected land imported seed of *Kochia scoparia* (L.) Schrader, an annual chenopod, from the United States. This seed, imported under routine quarantine procedure, was subsequently bulked up and has now been planted as a component of multispecies mixtures and pure stands on more than 60 properties in south-western Australia. *K. scoparia* is known to be a major weed of a broad range of agricultural and horticultural crops throughout the world, in addition to its involvement in stock poisoning. It is listed as a principal weed in Argentina and a common weed in the United States and Canada (Holm *et al*. 1979). *K. scoparia* is summer-growing and is not expected to have a major impact upon cropping in the mediterranean climate areas of south-western Australia. However, now that it is established in Western Australia, *K. scoparia* could pose a substantial threat to summer crops and fallows in eastern Australia until legal impediments to its movement to other States are instituted. *K. scoparia* has now been declared noxious by the Agriculture Protection Board of Western Australia. (NB, There are many recognized varieties of *K. scoparia*, at least one of which is non-weedy and has been grown in Australian gardens for many years (J. Dodd, personal communication)).

Ideally, all proposals to import new plants should be subjected to an assessment of the potential risks (and benefits) associated with importation. Furthermore, various interest groups should be able to express their opinions about the relative merit of proposed introductions. This paper, however, will deal only with the risks associated with introducing plant species to Australia.

Figure 1. Modes of introduction of Australian noxious weeds (n = 233; data from Parsons and Cuthbertson (1992).



A scoring system for potential weeds

Hazard (1988) first published a scoring system for decision-making in relation to the importation of plants (Table 1). The system was developed by S.W.L. Jacobs and will be referred to hereafter as System 1. In this section I will discuss some of the categories of attributes that were addressed in the scoring process. In the next section I present a modified system which is intended to reduce some problems of weighting, as well as the potential for misapplication.

Documented weedy behaviour

The basic problem with using biological and ecological attributes to evaluate weediness is that weeds as a group display many syndromes or combinations of such attributes (Barrett and Richardson 1986, Newsome and Noble 1986). There are no genetic, physiological or ecological characteristics that represent necessary and sufficient conditions for weediness. Accordingly, the most (and perhaps only) reliable basis for predicting weediness in Australia is documented weedy behaviour of the same taxon under similar climatic conditions elsewhere in the world. System 1 highlighted this, listing weed status elsewhere as grounds for rejection (Table 1). Comparison of a list of Australian noxious weeds ($n = 233$) (Parsons and Cuthbertson 1992) with world weed records (mainly from Holm *et al.* 1979), shows that approximately 90% of Australia's noxious weeds are considered to be weeds in one or more other countries (NB, some noxious weed declarations in Australia may have been based upon observations elsewhere). Unless similar or equivalent environmental conditions are absent in Australia, significant weed potential in Australia may be assumed from other weed records for a particular plant. Where weed records are not available, however, biological and ecological attributes remain the only bases for quarantine decision-making.

Taxonomic relationships

It is commonly assumed that a species that is closely related to a known weed would have a greater chance of being weedy than one more distantly related. Although there are some glaring exceptions (e.g., non-weedy populations of the weed *Eupatorium microstemon* Cass. (Baker 1965)), taxonomic position can embody information of a synthetic nature, similar to evidence of weedy behaviour. In System 1, a species with a weedy congener receives half of the score that leads to rejection (Table 1). My examination of the plants declared noxious in Australia (Parsons and Cuthbertson 1992) revealed that 87% of these species have weedy congeners.

Table 1. Scoring system for decision-making on the importation of plants (after Hazard 1988).

Criterion	Points
Is the species a free-floating (surface or submerged) aquatic or can it survive, grow and reproduce as a free-floating aquatic?	20[A]
Does the species have a history of being a major weed elsewhere in similar habitats?	20
Does the species have a close relative of similar biology with a history of weediness in similar habitats?	10
Are the plants spiny?	10
Does the plant have spiny diaspores? (i.e. burrs)	10
Are plants harmful to humans and/or stock?	8
Do plants produce stolons?	5
Do plants have other forms of vegetative reproduction?	8
Are the diaspores wind-dispersed?	8
Are the diaspores dispersed by mammals and/or machinery?	8
Are the diaspores dispersed by water?	5
Are the diaspores dispersed by birds?	5

[A] Scores totalling ≥ 20, between 12 and 19, or <12 indicate grounds for rejection, further examination or acceptance, respectively.

Table 2. Noxious species in relation to the total number of species naturalized in Australia.

Family	No. spp. naturalized[A]	No. spp. declared	% spp. declared
Boraginaceae	26	7	26.9
Solanaceae	58	14	24.1
Asteraceae	224	47	21.0
Euphorbiaceae	32	7	21.9
Cactaceae	29	6	20.7
Polygonaceae	27	5	18.5
Lamiaceae	42	7	16.7
Amaranthaceae	24	3	12.5
Liliaceae	56	6	10.7
Rosaceae	80	7	8.8
Brassicaceae	74	6	8.1
Poaceae	316	18	5.7
Fabaceae	173	7	4.0

[A] from Hnatiuk (1990).

A recent modification of System 1 gives weight to inclusion in particular families (e.g., Asteraceae, Brassicaceae and Amaranthaceae (Groves 1986)), allocating half the rejection score to these. However, affinity at this level is at best a weak predictor of weediness (Table 2), and for the nominated families, scoring for genus and family represents double counting

Noxiousness

Attributes that confer noxiousness should be of primary importance for scoring plants of unknown significance as weeds. Put simply, if a species is free of noxious properties, there is considerably less reason to exclude it. System 1 lists two noxious features, viz. whether a plant or its diaspores are spiny and the potential to harm humans and/or stock (Table 1). This group of attributes should be expanded (Table 3), if only to capture species that pose significant threats to the natural, as opposed to agricultural, environment (e.g., the climbing habits of *Anredera cordifolia* (Ten.) Steenis and *Macfadyena unguis-cati* (L.) A. Gentry, invaders of remnant rainforest communities in New South Wales). However, it is important to keep in mind that noxiousness is a legal, not a biological concept, and some potentially important weeds with unique or uncommon characteristics may be overlooked. Note that if competitiveness is scored as a noxious characteristic, many species of potential agronomic

Table 3. Characteristics conferring noxious status upon plant species.

Poisonous or unpalatable to stock
Harmful to humans
Producing spines, thorns or burrs
Competitive
Having a scrambling or climbing growth form
Parasitic on other plants

significance could require further assessment. Competitive ability depends upon a combination of plant characteristics, but these are all quantifiable (Grime 1979) and the methodology for examining competitive interactions between species is well developed (e.g., Firbank and Watkinson 1985).

Dispersal of diaspores

The rate of spread is of primary importance in determining how effectively a weed can be contained (Auld *et al.* 1978/79, Menz *et al.* 1980). Furthermore, Forcella (1985) provided evidence that final distributions are broader for weeds that demonstrate high initial rates of spread. As important as spread may be to the management of noxious weeds (Panetta 1987), System 1 appears to have given undue weighting to the mode of diaspore dispersal; should a species possess all four types of dispersal listed in Table 1, it would be rejected on the basis of dispersal characteristics alone! There is no data to support the relative weightings that have been given to different modes of dispersal (Table 1), and no guidelines exist for how regularly diaspores must be dispersed by a given mechanism for it to be scored.

System 1 modified

Prior to any assessment of the risks posed by its importation, a plant must be correctly identified. Although demonstrably weedy elsewhere, a taxon could be proposed for importation under a synonym or an erroneous name. In a recent case involving the Perth Zoological Gardens, three species of *Acacia* were imported for an African exhibit. One of these was imported as *A. arabica* (Lam.) Willd., but is known currently as *A. nilotica* (L.) Willd. ex Del., (Ross 1979), one subspecies of which is a proclaimed noxious weed in Queensland and the Northern Territory. Confirmation of identity by a recognized herbarium (Holmgren *et al.* 1990) would circumvent such problems.

Rather than summing points scored for each feature in Table 1, I propose restructuring the system on the basis of the relative reliability of the information under consideration (Figure 2). Thus weediness elsewhere is the primary criterion. It leads to immediate rejection if results from bioclimatic and other analyses (Panetta and Mitchell 1991a,b; Panetta 1992) indicate that a species could be preadapted to any environment within Australia.

Where no weed records exist for a species, it must be evaluated on the basis of less informative attributes. Consensus in the scientific community has been that the risk of invasion is too great to allow the introduction of any free-floating aquatic species; these may be rejected out of hand. The remainder of the scoring proceeds from an evaluation of noxiousness, as indicated in Figure 2.

Species with potentially noxious characteristics and having weedy congeners require further evaluation. Other bases for non-acceptance are demonstration of more than one type of reproductive behaviour (e.g., reproduction by both seed and vegetative structures), or more than one type of dispersal mechanism, (e.g., dispersal via animals and non-biotic vectors). It follows that the potential weeds most likely to escape detection by this system would have a combination of the following features: no close weedy relatives, a sole mode of reproduction (vegetative, or more likely, by seed) and a single, but very effective mode of dispersal.

Excluding the three species that are capable of living as free-floating aquatics (*Cabomba caroliniana*, *Egeria densa* and *Pistia stratiotes*), only 28 introduced noxious species (12%) have no weedy congeners (Table 4). When these are screened further, eight species would be accepted owing to the absence of multiple modes of reproduction and dispersal. However, six of these (*Cineraria lyrata*, *Ibicella lutea*, *Melianthus comosus*, *Martynia annua*, *Myagrum perfoliatum* and *Proboscidea louisianica*) would have been rejected either for possessing noxious characteristics or for a history of weediness elsewhere. With regard to the remaining plants (*Ecballium elaterium* and *Olea europaea*), the latter is probably the only species for which a case could be made for introduction today.

Rejection or further evaluation

The degree of confidence in the status of a candidate for introduction should be related to the reliability of the criteria employed for assessment. Thus, import should not be allowed for plants that are known to be weedy elsewhere and for which climatically suitable areas exist in Australia. Such organisms could be seen to pose clearly unacceptable risks to

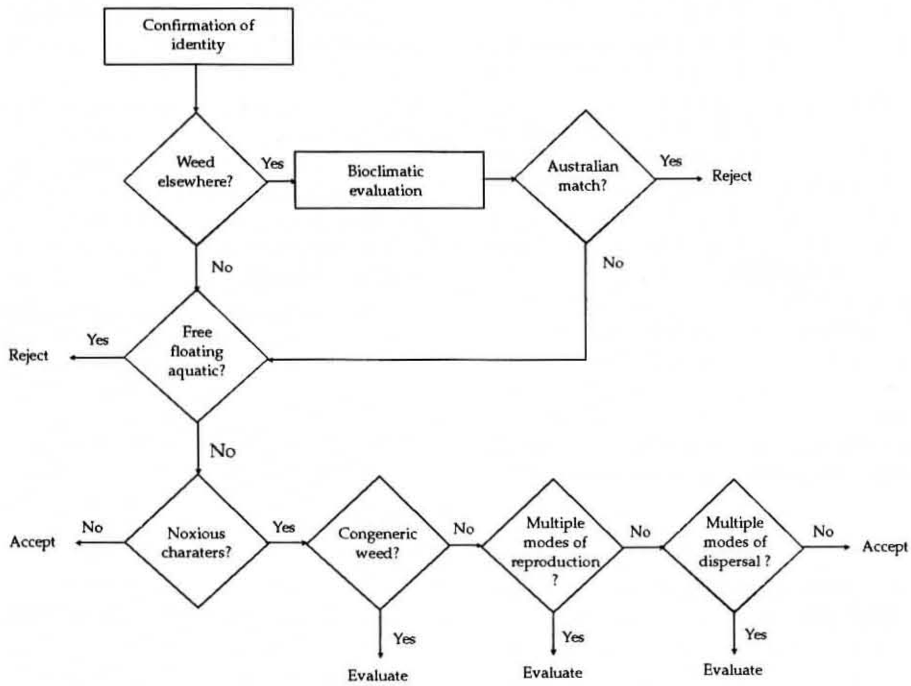
Table 4. Reproduction and dispersal characteristics of the Australian noxious weeds that have no close weedy relatives (n = 28). Plants capable of living as free-floating aquatics are not included.

Family	Species[A]	Multiple modes?	
		Reproduction	Dispersal
Apiaceae	*Conium maculatum*	no	yes
Apiaceae	*Foeniculum vulgare*	no	yes
Araceae	*Zantedeschia aethiopica*	yes	yes
Asclepiadaceae	*Cryptostegia grandiflora*	no	yes
Asparagaceae	*Myrsiphyllum asparagoides*	yes	no
Asteraceae	*Berkheya rigida*	yes	no
Asteraceae	*Chrysanthemoides monilifera*	yes	yes
Asteraceae	*Cineraria lyrata*[B]	no	no
Asteraceae	*Gorteria personata*	no	yes
Asteraceae	*Gymnocoronis spilanthoides*	yes	no
Asteraceae	*Silybum marianum*	no	yes
Asteraceae	*Stevia eupatoria*	yes	yes
Brassicaceae	*Hirschfeldia incana*	no	yes
Brassicaceae	*Myagrum perfoliatum*[B]	no	no
Caesalpiniaceae	*Parkinsonia aculeata*	no	yes
Cucurbitaceae	*Ecballium elaterium*[B]	no	no
Euphorbiaceae	*Eremocarpus setiger*	no	yes
Fabaceae	*Dalbergia sissoo*	yes	no
Iridaceae	*Watsonia bulbillifera*	yes	no
Martyniaceae	*Ibicella lutea*[B]	no	no
Martyniaceae	*Martynia annua*[B]	no	no
Martyniaceae	*Proboscidea louisianica*[B]	no	no
Melianthaceae	*Melianthus comosus*[B]	no	no
Oleaceae	*Olea europaea*[B]	no	no
Poaceae	*Nasella trichotoma*	no	yes
Simaroubaceae	*Ailanthus altissima*	yes	yes
Verbenaceae	*Gmelina asiatica*	yes	no
Zygophyllaceae	*Peganum harmala*	no	yes

[A] authorities as in Parsons and Cuthbertson (1992).

[B] plants that would be accepted according to the assessment system.

Figure 2. A screening system for proposed plant introductions.



agriculture and the environment. From an agronomic or horticultural point of view, it is questionable whether introduction should be considered for non-intensive enterprises if the climatic suitability within Australia is predicted to be marginal. However, some weeds, particularly those originating in Europe and the Mediterranean Basin, have colonized parts of Australia that have different climatic characteristics to their source regions (Michael 1981).

Potential risks based upon relatedness, reproduction, or dispersal characteristics (Figure 2) could be evaluated in terms of evidence for non-weediness. Such evidence might include a documented lack of weedy behaviour from previous introductions in climatically similar world regions (by analogy to the initial screening procedure). However, unless appropriate evidence exists in the literature or in other reliable forms, strictly controlled introduction at one or more sites may be required in order to properly evaluate the weediness of the candidate.

While the need for security would preclude an assessment of dispersal potential, features which could be examined include characteristics of seeds and seed banks, growth rates, competitiveness, capacity for vegetative regeneration, age at first reproduction, fecundity and attack by natural enemies. An appraisal of the candidate's susceptibility to commonly used herbicides should also be made at this stage. Such a process would undoubtedly be costly and time-consuming. If proponents had to bear the cost, it is likely that more effort would go into the selection of candidates for importation.

The proposed assessment system also has relevance to the accidental introduction of weeds (Figure 1), which can occur via contamination of imported goods. Currently the Australian Quarantine and Inspection Service assigns pests to one of four categories of risk status, reflecting their perceived or potential biological and economic impacts. A maximum pest level (MPL) has been established for each class and represents the level of contamination that should not be exceeded for a consignment (Panetta 1990). Where a weed contaminant is identifiable, the present system could help to determine its risk status, hence the appropriate MPL.

Discussion

The strength of the present assessment system is that it segregates categories of information that have different predictive values. The most reliable basis for prediction of weedy behaviour in Australia must be evidence for weedy behaviour elsewhere. There are a number of problems associated with bioclimatic extrapolation to Australian environments, including non-correspondence of the climatic characteristics of source and colonial regions for some weeds (Michael 1981), the existence of unsuspected secondary climatic optima for species (Vickery 1974) and the possibility of differences in genetically-based climatic responses between weed populations (Panetta and Mitchell 1991b). However, the use of relatively non-restrictive criteria for climate matching will maintain a conservative approach to quarantine decision-making (Panetta 1992).

The remaining information in System 1 has substantially less predictive value. It should not be used in conjunction with direct evidence of weediness, since any resultant score would be distorted owing to a combination of inappropriate weighting (one point derived from 'weed elsewhere' is equivalent to one point from 'wind dispersal') and double counting (scoring weedy attributes for proven weeds). The danger in this application of System 1 is that species may ultimately be prioritized for exclusion on the basis of sums dominated by scores for unreliable characteristics. Biological and ecological attributes should be utilized primarily when there is no other evidence for weed potential. Furthermore, insufficient information for any characteristic should justify rejection of a candidate.

Australasian plant communities have been invaded by introduced species exhibiting a variety of life forms, physiological and reproductive characteristics (Newsome and Noble 1986, Timmins and Williams 1987, Humphries *et al.* 1991). Owing to the much higher structural and floristic diversity that exists in natural communities, it is more difficult to identify potential 'environmental', as opposed to agricultural, weeds. In a recent study examining all of the southern African species that are naturalized in Australia, 43% of the variation in agricultural weed status in Australia could be explained by weed status in the region of origin. No significant predictors were found for environmental weeds, however (Scott and Panetta 1993). Identifying such plants prior to their introduction will remain a major challenge to both scientists and quarantine personnel.

Conclusions

This paper has addressed the risk variable in a risk/benefit relationship. It is unlikely that potential benefits would ever be great enough to justify the import of a candidate that was rejected on the basis of a history of weediness. However, candidates that are flagged by this system on the basis of taxonomic affinity or their biological and ecological features may ultimately be approved for introduction if there is evidence for non-weedy behaviour following introductions elsewhere. Alternatively, they may promise substantial benefits and conflicts of interest may be either absent or resolvable.

Given the fact that we possess an imperfect understanding of the features that confer weediness, a simple screening system is bound to reject a number of harmless plants and to accept others that could prove to be damaging in the long run. The latter fault is more serious by far (Panetta 1992). Where there is uncertainty about potential risks, candidates for introduction should be grown under secure conditions in a number of environments so that further assessments of weed potential may be made. In relation to the introduction of pasture species, Hazard (1988) has commented that the costs involved in such a procedure would be small compared to the ever-increasing expenditure on weed control campaigns mounted against plants now regarded as major weeds. One can only hope that the rapid recognition of the weed potential of *K. scoparia* following its legitimate introduction in Western Australia will preclude the introduction of this species to New South Wales and Queensland. While the performance of Australian quarantine services has been exemplary regarding the exclusion of diseases and animal pests, it is imperative that the quarantine net now be tightened with regard to weeds.

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