Indian Journal of Weed Science **46**(1): 91–95, 2014

Predicting invasive plants using weed risk assessment

Mool Chand Singh* and Madhu B. Priyadarshi[1]

Division of Plant Quarantine, National Bureau of Plant Genetic Resources, New Delhi 110 012

Received: 16 January 2013; Revised: 12 Feerbuary 2014

ABSTRACT

Seeds and planting materials of different plant species are being imported into India. Many of these plants have the potential to become agricultural or environmental weeds and this risk needs to be assessed before allowing their entry. Weed risk assessment is a question based scoring system, containing 49 questions about the species. The questions include details of the plant's climatic preferences, biological attributes, dispersal methods and reproduction. A minimum number of questions must be answered before an assessment is made. The weed risk assessment uses responses to the questions to generate a numerical score that is positively correlated with weediness. The assessment method was tested against 170 plants representing both weeds and useful plants from agriculture and environment. The method was judged on its ability to correctly reject weeds and accept non weeds. A total of 40% plants were classified as serious weeds, 30% as common weeds and remaining 30% were non weeds. The system is designed to be operated by plant quarantine officers. The weed risk assessment system with explicit scoring of biological, ecological and geographical attributes is a useful tool for detecting potentially invasive weeds in other areas of the world.

Key words: Plant Quarantine, Score, Seeds, Weed, Weed risk assessment

The implementation of new policy on 'Seed Development' by the Government of India has provided stimulus for the import of seeds of various crops from all over the world. This has increased the risk for the introduction of exotic weeds into India. Weeds have major impacts on economies and natural environments worldwide including India. Many of these weeds have been purposely introduced as new crops or as ornamentals. To counter the threat to agriculture or the environment from new plants, regulatory authorities have a statutory responsibility to ensure that all plants proposed to be imported, which are not already established, be evaluated for their potential to damage the productive capacity or environment of the country. Quarantine in India officially came into operation with the passing of the Destructive Insects & Pests Act (DIP Act) in 1914. Plant Quarantine Order 2003 (regulation of import into India), of the Destructive Insects and Pests Act (1914) provides a legislative framework for the application of measures to prevent the introduction or spread of insect, disease and weed pests affecting plants. Effective plant quarantine is important for the protection of the biodiversity of the natural environment and agricultural productivity. Infestation of agricultural system has the potential not only to incur costs in controlling pests and losses in production, but also to restrict access to export markets, if the pest has the potential to contaminate the marketable product. There are many approaches to predicting weed potential (Mack 1996), but there is an urgent need of an objective, credible and publicly acceptable risk assessment system to predict the weediness of the new plant introductions.

An acceptable weed risk assessment system should satisfy a number of requirements. It should be calibrated and validated against a large number of plants already present in the recipient country and representing the full spectrum of plants likely to be encountered as imports into that country. It must discriminate between weeds and non-weeds, such that the majority of weeds are not accepted, non-weeds are not rejected, and the proportion of plants requiring further evaluation is kept to a minimum. As international trade agreements require that prohibited plant should fit in the definition of a quarantine pest before they can be excluded by quarantine regulations (Singh *et al.* 2005), the system must be passed on explicit assumption and scientific principles so that country +cannot be accused of applying unjustified non-tariff trade barriers. Ideally, the system should be capable of identifying which land use system the plant is likely to invade, to assist in an economic evaluation of its potential impacts. Finally, the system must be cost

***Corresponding author:** mchsingh@gmail.com

[1]AKMU Cell, National Bureau of Plant Genetic Resources, New Delhi 110 012

effective. This 'weed risk assessment' (WRA) system for India is designed in consultation with the weed scientists of Australia, University of Queensland, Brisbane.

Methodology of weed risk analysis (WRA)

The WRA system is designed to run on Microsoft Excel 2007 in MS Windows operating system. The basis of the WRA is to answers 49 questions (Table 1) based on the main attributes and impacts of weeds. These are combined into scoring system which in the absence of any evidence to the contrary, gives an equal weight to nearly all questions (Tabel 2). These cover a range of weedy attributes in order to screen for plants that are likely to become weeds of an environment and/or agriculture. The questions are divided into three sections producing identifiable scores that contribute to the total score (Table 2). Most questions are answered, as yes, no or don't know. Biogeography consists the documented distribution, climate preferences, history of cultivation, and weediness of a plant elsewhere in the world, *i.e.* apart from the proposed recipient country. Weediness elsewhere is a good predictor of a plant becoming a weed in new areas with similar environmental conditions (Forcella and Wood 1984). The questions concerning the history of cultivation recognizes the important human component of propagule pressure (Williamson and Fitter 1996), but such data are obviously never available for the proposed new country. The global distribution and climate preferences, where these are available, are used to predict a potential distribution in the recipient country. Undesirable attributes are characteristics such as toxic fruits and unpalatibility, or invasive behavior, such as a climbing or smothering growth habit, or the ability to survive in dense shade. Biology and ecology are the attributes that enable a plant to reproduce, spread and persist (Noble 1989) such as whether the plant is wind dispersed or animal dispersed, and whether the seeds would survive through passage of an animal's gut. Availability of information is often very limited for new species which can restrain the utility of screening systems. To ensure that at least some questions were answered for each section, the WRA system requires the answer to two questions in Section-A, two in Section- B and six in Section-C before it will give an evaluation and recommendation. The recommendation can be compared with the number of questions, answered as an indication of its reliability which obviously improves as more questions are answered.

Answers to the questions provide a potential total score ranging from -14 (benign plant) to 29 (maximum weediness) for each plant. The total score is partitioned between answers to questions considered to relate primarily to agriculture, to the environment, or common to both (Table 1). The total scores are converted to one of the three possible recommendations by two critical score settings. The lower critical scores 0, separates 'acceptable' plants from those requiring 'evaluation', and the higher critical score, 6, separates plants requiring 'evaluation' from those that should be 'rejected'. Evaluation could mean either obtaining more data or re-running the system, or undertaking further investigations such as field trails (Mack 1996). The model was run to assess the weed potential of plants ranging from beneficial plants to serious weeds.

Interference of results of WRA

The answer to most of the questions in WRA is yes (y), *no* (n) or don't know (leave blank or?). The system translates these responses into a numerical score.

A typical score for a question is Yes=1 point, No= -1 or 0 and don't know/? =0

The questions in Sections- 2 and -3 (climate and weed elsewhere) of the questionnaire differ from the typical scoring in that they generate a score by a weighting system. The score given for questions 2.01 and 2.02 is used to weight the scores for 'yes' answers in the weed elsewhere questions (3.01 to 3.05). The quality of climate data greatly affects the climate match. A good climate match increases the probability that a weedy species will behave the same way in India as it does overseas. The weediness score also increases if the information used to produce the climate match is not comprehensive, due to the greater uncertainty introduced by this data.

Two other questions do not fit into the standard scoring system:

1) A score of 'no' for question 3.01, whether a plant has naturalized overseas, is modified by the score to question 2.05, its history of repeated export species with repeated introductions outside of their native range that have not established are a lower risk.

2) Questions 6.07, the minimum generative time, require the input of a numerical score. This generative time is standardized by the use of correlation factor as shown in table.

Reproduction	Scores
< 1 to 2 years	1
Between 2 to 4 years	0
Greater than or equal to 4 years	-1

Table 1. Weed risk assessment system question sheet

Botanical Name:	*Phalaris paradoxa*	Outcome:	Reject
Common Name:	Paradoxa grass	Score:	12
Family Name:	Poaceae	Your name:	M.C. Singh

Section	Weed Type	S.no.	a Question	b Response	c Score	d N Score	e Y Score
Domestication/ cultivation							
A	Common	1.01	Is the species highly domesticated? If answer is no go to question 2.01	N	0	0	-3
A	Common	1.02	Has the species become naturalised where grown?			-1	1
A	Common	1.03	Does the species have weedy races?			-1	1
Climate and distribution							
A		2.01	Species suited to Indian climates (0-low; 1-intermediate; 2-high)		2		
A		2.02	Quality of climate match data (0-low; 1-intermediate; 2-high)		2		
A	Common	2.03	Broad climate suitability	N	0	0	1
A	Common	2.04	Native or naturalised in regions with extended dry periods.	N	0	0	1
A		2.05	Does the species have a history of repeated introductions outside its natural range?				
A	Weed elsewhere						
A	Common	3.01	Naturalised beyond native range	Y	2		
A	Environmental	3.02	Garden /amenity / disturbance weed	N	-1		
A	Agricultural	3.03	Weed of agriculture /horticulture / forestry	Y	4		
A	Environmental	3.04	Environmental Weed	N	-1		
A	Common	3.05	Congeneric weed Undesirable				
Undesirable traits							
B	Common	4.01	Produces spines, thorns or burrs	N	0	0	1
B	Common	4.02	Allelopathic	N	0	0	1
B	Common	4.03	Parasitic	N	0	0	1
B	Agricultural	4.04	Unpalatable to grazing animals	N	-1	-1	1
B	Common	4.05	Toxic to animals	N	0	0	1
B	Common	4.06	Host for recognised pests and pathogens			0	1
B	Common	4.07	Causes allergies or is otherwise toxic to humans	N	0	0	1
B	Environmental	4.08	Creates a fire hazard in natural ecosystems	N	0	0	1
B	Environmental	4.09	Is a shade tolerant plant at some stage of its life cycle			0	1
B	Environmental	4.10	Grows on infertile soils			0	1
B	Environmental	4.11	Climbing or smothering growth habit			0	1
B	Common	4.12	Forms dense thickets plant type	N	0	0	1
Plant type							
C	Environmental	5.01	Aquatic	N	0	0	5
C	Common	5.02	Grass	Y	1	0	1
C	Environmental	5.03	Nitrogen fixing woody plant	N	0	0	1
C	Common	5.04	Geophyte			0	1
Reproduction							
C	Common	6.01	Evidence of substantial reproductive failure in native habitat			0	1
C	Common	6.02	Produces viable seed	Y	1	-1	1
C	Agricultural	6.03	Hybridises naturally			-1	1
C	Common	6.04	Self-fertilisation	Y	1	-1	1
C	Common	6.05	Requires specialist pollinators	N	0	0	-1
C	Agricultural	6.06	Reproduction by vegetative propagation	N	-1	-1	1
C	Common	6.07	Minimum generative time (years) (Answer between 1,2, 0r 4 value)	1	1		
Dispersal mechanisms							
C	Agricultural	7.01	Propagules likely to be dispersed unintentionally	N	-1	-1	1
C	Common	7.02	Propagules dispersed intentionally by people	Y	1	-1	1
C	Agricultural	7.03	Propagules likely to be disperse as a produce contaminant			-1	1
C	Common	7.04	Propagules adapted to wind dispersal	Y	1	-1	1
C	Environmental	7.05	Propagules buoyant			-1	1
C	Environmental	7.06	Propagules bird dispersed	Y	1	-1	1
C	Common	7.07	Propagules dispersed by other animals (externally)	N	-1	-1	1
C	Common	7.08	Propagules dispersed by other animals (internally)	Y	1	-1	1
Biological attributes							
C	Common	8.01	Prolific seed production	Y	1	-1	1
C	Common	8.02	Evidence that a persistent propagule bank is formed (> 1 year)	Y	1	-1	1
C	Agricultural	8.03	Well Controlled by herbicides	Y	-1	1	-1
C	Agricultural	8.04	Tolerates or benefits from multilation, cultivation or fire			-1	1
C	Common	8.05	Effective natural enemies present in India	N	-1	-1	1

Result

Weed Type	
Agricultural	5
Environmental	6
Common	22

Excluding common weed and comparing agricultural and environmental weed towards the higher side leads to the conclusion of environmental weed

Section Attended

A	7
B	8
C	18
Total	33
Outcome:	Reject

Table 2. Weed risk assessment system question sheet

Section	Weed Type	a Question	b Response [1]	c Score [2]	d N Score	e Y Score
	C	1.01			0	-3
A	C	1.02			-1	1
A	C	1.03			-1	1
A		2.01				
A		2.02				
A	C	2.03				
A	C	2.04				
A		2.05				
A	C	3.01				
A	E	3.02				
A	A	3.03				
A	E	3.04				
A	C	3.05				
B	C	4.01			0	1
B	C	4.02			0	1
B	C	4.03			0	1
B	A	4.04			-1	1
B	C	4.05			0	1
B	C	4.06			0	1
B	C	4.07			0	1
B	E	4.08			0	1
B	E	4.09			0	1
B	E	4.10			0	1
B	E	4.11			0	1
B	C	4.12			0	1
C	E	5.01			0	5
C	C	5.02			0	1
C	E	5.03			0	1
C	C	5.04			0	1
C	C	6.01			0	1
C	C	6.02			-1	1
C	A	6.03			-1	1
C	C	6.04			-1	1
C	C	6.05			0	-1
C	A	6.06			-1	1
C	C	6.07				
C	A	7.01			-1	1
C	C	7.02			-1	1
C	A	7.03			-1	1
C	C	7.04			-1	1
C	E	7.05			-1	1
C	E	7.06			-1	1
C	C	7.07			-1	1
C	C	7.08			-1	1
C	C	8.01			-1	1
C	C	8.02			-1	1
C	A	8.03			1	-1
C	A	8.04			-1	1
C	C	8.05			-1	1

Response for these questions is 2 unless a climate analysis is done.

Refer to lookup table

Lookup table for section 3.
Locate value of inputs and lookup output for each question

Yes to question 3.01 – 3.05										default
Inputs	2.01	0	0	0	1	1	1	2	2	2
	2.02	0	1	2	0	1	2	0	1	2
Results	3.01	2	1	1	2	2	1	2	2	2
	3.02	2	1	1	2	2	1	2	2	2
	3.03	3	2	1	4	3	2	4	4	4
	3.04	3	2	1	4	3	2	4	4	4
	3.05	2	1	1	2	2	1	2	2	2

No to question 3.01-3.05				
Input	2.05	?	N	Y
Results	3.01	-1	0	-2
	3.02-3.05	0	0	0

Procedure

1. Record appropriate responses in column b.
2. Look up score in columns d & e and record result in column c.
3. Calculate total score.
4. Lookup and record recommendation
5. Verify that minimum number of questions from each section is answered.
6. Compute Agricultural (A& C) and environmental (E& C) scores: If either score is less than 1, the outcome pertains to the other sector.

Lookup table for 6.07

years	1	2	4
score	1	0	-1

Score	Outcome
<1	Accept
1 -6	Evaluate
< 6	Reject
Section	**Minimum # question [5]**
A	2
B	2
C	6
Total	10

Total Score [3]	
Outcome [4]	
Agriculture [6]	
Environment [6]	

Weed Type	
A	Agricultural
E	Environmental
C	Common

The WRA compares the total score for a species to the critical values to determine the recommendation for the species. The threshold values for the system are shown as follows:

If the plant scores less than 1	Accept the plant
if the plant scores greater than 6	Reject the plant
if the plant scores between 1 to 6	Plant requires further evaluation

The species used for the calibration of the system ranged from severe agricultural and environmental weeds to benign and beneficial plants. The WRA tallies the number of questions answered in each section. The WRA allows for a minimum number of questions in each of its three different categories. The minimum number of questions for each section is: 2 for Section- A, 2 for Section- B and 6 for Section- C. When using the; Excel Spreadsheet', if the minimum number of questions is not completed, a message that more information is required is posted by the system. The WRA has some capacity to suggest the type of ecosystem likely to be affected by the plant assessed. The WRA indicates if the plant is more likely to be a specific weed of agriculture or the general environment, once it has assessed the plants potential to become a weed in India. A species may be assessed to be a weed of both categories. The partitioning helps to identify areas most at risk from the characters assessed for the species. The assessment method was tested against 170 plants representing both weeds and useful plants from agriculture and environment. The method was judged on its ability to correctly reject weeds and accept non weeds. A total of 40% plants were classified as serious weeds, 30% as common weeds and remaining 30% were non weeds.

The system identifies a wide range of weeds, and does not accept plants known to be major weeds in India. By splitting the total scores the model also allows an estimate of whether the weed is more likely to impact on agricultural or natural environment systems, which may assist regulatory authorities in making a recommendation. These features suggest that the system could be altered and still be expected to produce satisfactory results in other bio-climatic regions of the globe where protocols are lacking (Ruesink *et al.* 1995). As the system is simple and spreadsheet based, it can be used by lay people who wish to import plants and it has an educational role because it shows the effect of individual questions on the total score. The system distinguishes between many useful and non useful plants, but some useful plants can be rejected. This is to be expected, because planned introductions are chosen for their ability to survive (Ruesink *et al.* 1995), and the questions asked by the system are based primarily on biological and ecological criteria which identify attributes common to both useful agricultural plants and weeds (Lonsdale 1994). These may differ only in a small number of characteristics within any single life from (Perrins *et al.* 1992). Where a plant may have significant economic benefits, a further evaluation of its weediness potential may include experimental studies (Williamson, 1993, Scott and Panetta 1993). Economic value should be scored in a transparently separate exercise and balanced against weediness in appropriate risk assessment evaluations (Singh *et al.* 2005).

It is concluded that the Weed Risk Assessment System with explicit scoring of biological, ecological and geographical attributes is a useful tool for detecting potentially invasive weeds in other parts of the world and should be used in Indian Plant Quarantine to assess the plants before issue of the *Import Permit.*

REFERENCES

Forcella F and Wood TJ. 1984. Colonization potentials of alien weeds are related to their native distribution- implications for plant quarantine. *Journal of Australian Institute of Agricultural Science* **50**: 35-41.

Lonsdale WM. 1994. Inviting trouble: introduced pasture species in northern Australia. *Australian Journal of Ecology* **19**: 345-354.

Mack RN. 1996. Predicting the identity and fate of plant invaders: emergent and emerging approaches. *Biological Conservation* **78**: 107-121.

Noble IR. 1989. Attributes of invaders and the invading process: terrestrial and vascular plants. pp. 301-310.In: *Biological Invasions: A Global Perspective* (Eds. JA Drake, HA Mooney, FD Castri, RH Groves, FJ Kruger, M Rejmanek and M Williamson). Chichester: John Wiley.

Perrins J, Williamson M and Fitter A. 1992. A survey of differing views of weed classification: implifications for regulating introductions. *Biological Conservation* **60**: 47-76.

Ruesink JL, Parker IM, Groom MJ and Kareiva PM. 1995. Reducing the risks of nonindigenous species introductions. *Bioscience* **45**: 465-477.

Scott JK and Panetta FD. 1993. Predicting the Australian weed status of southern African plants *Journal of Biogeography* **20**: 87-93.

Singh MC, Gnansambandham S and Chandurkar PS. 2005. Weeds as quarantine pests. *Plant Protection Bulletin*. **57**: 1-3.

Williamson M. 1993. Invaders, weeds and the risk from genetically manipulated organisms. *Experimentia* **49**: 219-224.

Williamson M and FitterX FD. 1996. The characteristics of successful invaders. *Biological Conservation* **78**: 163-170.