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ANALYSIS ARTICLE

Indian quarantine weeds invasiveness assessment using bio-security tool: Weed Risk Assessment

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ABSTRACT

Introduced plants may contribute to the economic losses to agriculture and exert a substantial financial burden on the resources available for the management of natural areas. Most of these taxa have the ability to become agricultural or environmental weeds, and therefore prior to permitting their entry, the risk/s needs to be evaluated. Weed risk assessments (WRA) are used to identify plant invaders before introduction. Thus, in order to recognize plant introductions that are likely to cause damage, we examined the weed risk assessment (WRA) of quarantine weeds (Gazette notification issued on 24th October, 2019), that are listed in Schedule VIII of Plant Quarantine Order, 2003 issued under the Destructive Insect & Pest Act (1914) of India. The weeds species selected for the present study are already included in the quarantine weeds list. However, the data on how much risk is posed by these weed species is not available in Indian context. Therefore, we have made an attempt to assess of risk posed by these weed species. The present study revealed that among the evaluated 54 species, 33, 16 and 4 species showed high risk, intermediate risk and low risk, respectively. The highest WRA score (35) was recorded for the species *Senecio inaequidens* DC. The WRA score 34 was recorded for 3 species namely *Centaurea diffusa* Lam., *Senecio jacobaea* L. and *Solanum carolinense* L. Amongst these weeds the lowest WRA score (16) was observed in case of *Cichorium spinosum* L.

Keywords: High risk, Intermediate and low risk species, Plant invaders, Quarantine weeds, Weed risk assessment (WRA)

INTRODUCTION

It is predicted that by 2050 the world's population will surpass 9 billion. Global food production needs to be increased by 70 to 100% to feed this population (www.fao.org). In both developing and developed countries, weeds are the most significant biotic threats to agricultural production. Weeds typically have the maximum potential for agricultural productivity reduction, along with pathogens (fungi, bacteria, *etc*.) and animal pests (insects, rodents, nematodes, mites, birds, *etc*.) that are less of a concern (Oerke 2006). The economic losses due to weeds on the Indian economy was estimated to be around USD 11 billion in ten crops alone (Gharde *et al.* 2018).

Invasive plants (weeds) cause considerable damage to the ecosystem, reduce crop yields and raise farm production costs (Sinden *et al.* 2004, Rao *et al.* 2020). The management of the risks of entering, developing and becoming invasive of new plant species is dependent on the presence of an appropriate regulatory system and the ability to evaluate which plant species should be controlled.

Invasive plants come under the Convention on Biological Diversity (http://www.cbd.int) and International Plant Protection Convention (IPPC) (www.ippc.int). The IPPC mainly emphasizes on quarantine measures to avoid the introduction and spread of species that damage plants and plant products. Most of those IPPC International Phytosanitary Measurement Standards (ISPMs) are important for controlling the entry of new species.

Regulatory methods for actively introducing new plant species differ. Several countries do not have substantial border controls while others do have stringent border controls that require detailed risk assessments and approval to import and release a new species. For instance, both Australia and New Zealand have regulatory processes in place that require anyone planning to apply for approval to introduce a new species into these countries. If the species is not already on the approved list, the governing authority will conduct an assessment of the new species' invasive potential. If the possibility of

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invasiveness is deemed to be low enough, then consent is given to import and release, and the species is included on the approved list. If the invasive potential is deemed undesirable then the species are not allowed to import and release, and the species is listed on the restricted list. If there is limited information given to perform a risk assessment, permission may be denied until further information is provided and a reassessment can be carried out (Roberts *et al.* 2001).

The concept of quarantine acts in India began in the early 20th century when the British government ordered mandatory fumigation of imported cotton bales in 1906 to prevent the entry of the dreaded Mexican cotton boll weevil (*Anthonomus grandis* Boh.). On 3rd February 1914, the Destructive Insects and Pests Act (DIP Act) was introduced. The DIP Act (1914) has been revised over the years, and has been amended many times. However, it needs to be revised and updated regularly to address the demands of liberalized trade under the WTO. The Directorate of Plant Protection, Quarantine and Storage (DPPQS) was established under the Ministry of Food and Agriculture in 1946 and the plant quarantine operation was launched in 1946 by the Botany Division at the Indian Agricultural Research Institute (IARI), New Delhi. DPPQS began its quarantine activities at Bombay seaport in October 1949. First plant quarantine and fumigation station were officially inaugurated in India on 25th December, 1951. National Plant Genetic Resource Bureau (NBPGR) was established in August 1976. The Plant Quarantine Division was established in 1978, with the sections of Entomology, Plant Pathology and Nematology. The Plants, Fruits and Seeds (Regulation of Import into India) Order, popularly known as PFS Order, came into effect in October 1988 (Chand 2017).

A risk and risk assessment should be conducted before a conclusion is made on management of a weed species. The degree of risk imposed by an invading species depends on a variety of factors: its possible effects, including the overall area of its invasion; its spread rate and control sensitivity, along with its detectability. While these elements can also be modelled if there is ample information available, this is rarely the case with invasive plants and less quantitative approaches need to be implemented. One such collection of approaches, weed risk management systems (WRM) typically compare the characteristics of the species on specific qualitative levels.

Weed risk assessments (WRA) are used to identify plant invaders before introduction (Caton *et al.* 2018). The Australian WRA has been used in Australia since 1997 as an integral part of the federal regulatory framework for planned new plant introduction (Weber *et al.* 2009). This WRA has been adopted or evaluated, sometimes with minor modifications to suit local conditions, by others. For example, the WRA system has also been tested at varying levels in Japan (Kato *et al.* 2006, Nishida *et al.* 2009), the Czech Republic (Køivánek and Pyšek 2006), the U.S.A. (Gordon and Gantz 2008), Florida, U.S.A. (Gordon *et al.* 2008), Hawaii, U.S.A. (Daehler and Carino 2000), Tanzania (Dawson *et al.* 2009) and the Pacific Islands (Daehler *et al.* 2004).

WRA is required to make wise decisions about the best way of managing weeds on public land in India. To date, no previous risk assessment has investigated on quarantine weed species and there has been no evaluation of the quarantine weeds using WRA tool. Whereby, we strive to provide managers and policy makers with an appropriate method for managing new and emerging plant incursions (native or non-native) and building skills and capacity for the future in India, as well as helping to raise awareness of risks and action needs. These techniques have potential to solve contemporary problems in futuristic agriculture weed management practices. Thus, we examined the WRA using Quarantine weeds (Gazette Notification issued on 24th October, 2019) which are listed in Schedule VIII of Plant Quarantine (Regulation of Import into India) Order (2003), issued under the DIP Act 1914. The objective of the present study was to examine invasiveness of quarantine weeds, potential distribution and the influences on agricultural, economic, and environmental values using WRA method.

MATERIALS AND METHODS

Weed risk assessment method

Any exotic species that is not yet currently present in a particular region, has a small range in the risk field, and is expected to be introduced and commercially used on a wide scale are plant species deemed appropriate for risk assessment. For bio-geographical, ecological, and experience-related elements, the scoring system allocates ratings to the species. The scores of the 12 questions are summed up, and species are classified into high risk, intermediate risk, and low risk species. The details of the 12 questions are given in the **Table 1** (Singh *et al.* 2020). Weed species whose score value range from 3-20 will be categorized as low risk, 21-27 score will be categorized as intermediate risk and 28-39 will be categorized as high-risk species.

Table 1. Details of 12 question in weed risk assessment (WRA) (Singh *et al.* 2020)

1. Climatic match	Score
Does the known geographical distribution of the species include eco climatic zones similar with those of the risk area?	
• No	0
• Yes	2
2. Status of species in India	
Is the species native to India?	
• No	0
• Yes	2
3. Geographic distribution in India	
In how many countries does the species occur?	
• Species occurs in 0 or 1 country	1
• Species occurs in 2–5 countries	2
• Species occurs in >5 countries	3
4. Range size of global distribution	
How is the size of the global range (native and introduced)?	
• Range is small, species is restricted to a small area within one continent	0
• Range is large, extending over more than 15° latitude or longitude in one continent or covers more than one continent	3
5. History as an agricultural weed elsewhere	
Is the species reported as a weed from somewhere else?	
• No	0
• Yes	3
6. Taxonomy	
Does the species have weedy congeners?	
• No	0
• Yes	3
7. Seed viability and reproduction	
How *many* seeds do the species approximately produce?	
• Few seeds or no viable seeds	1
• Many seeds	3
• Do not know	2
If the species is present in the risk area, this question refers to plants within the risk area. If the species is present in Europe, this question refers to plants within the European range. If the species is not present in Europe, this question refers to the native or introduced range of the species	
8. Vegetative growth	
Allocate species to one of the following. If more than one statement applies, take the one with the highest score.	
• Species has no vegetative growth that leads to lateral spread	1
• If a tree or shrub, species has the ability to resprout from stumps or stem layering, or stems root if touching the ground	2
• Species has bulbs or corms	1
• Species has well developed rhizomes and/or stolons for lateral spread	4
• Species fragments easily, fragments can be dispersed and produce new plants	2
• Other or do not know	2
9. Dispersal mode	
Allocate species to one of the following. If more than one statement applies, take the one with the highest score.	
• Fruits are fleshy and smaller than 5 cm in diameter	2
• Fruits are fleshy and larger than 10 cm in length or diameter	0
• Fruits are dry and seeds have well developed structures for long-distance dispersal by wind (pappus, hairs, wings)	4
• Fruits are dry and seeds have well-developed structures for long-distance dispersal by animals (spikes, thorns)	4
• Species has mechanisms for self-dispersing	1
• Other or do not know	2
10. Lifeform	
• Species is a small annual (< 80 cm)	0
• Species is a large annual (>80 cm)	2
• Species is a woody perennial	4
• Species is a small herbaceous perennial (< 80 cm)	2
• Species is a large herbaceous perennial (>80 cm)	4
• Species is a free-floating aquatic	4
• Other	2
11. Habitats of species	
Allocate species to one of the following. If more than one statement applies, take the one with the highest score	
• Riparian habitats	3
• Bogs/swamps	3
• Wet grasslands	3
• Dry (xeromorphic) grasslands	3
• Closed forests	3
• Lakes, lakeshores, and rivers	3
• Other	3
12. Population density	
What is the local abundance of the species	
• Species occurs as widely scattered individuals	1
• Species forms occasionally patches of high density	2
• Species forms large and dense monocultures	4

Selection of plant species

We examined the WRA using 57 quarantine weeds (Gazette Notification issued on 24th October, 2019) which are listed in Schedule VIII of Plant Quarantine (Regulation of Import into India) Order (2003) issued under the DIP Act 1914.

Data collection

Assessment was made at ICAR-Directorate of Weed Research (DWR) in collaboration with Division of Plant Quarantine, ICAR-National Bureau of Plant Genetic Resources (NBPGR), New Delhi. A test to compare the model is problematic, since there are no absolute values for individual taxa's weediness (Perrins *et al.* 1992). However, anyone familiar with a taxon in a country may give a reasonable opinion on the taxon's real or possible weediness in that country, to which the score from the model can be compared. For this study, we analyzed the data collected from existing literature on-line databases (www.cabi.org/ isc/ datasheet) and the internet (*i.e.*, using Google searches based on species name) in order to address the questions. The number of questions answered in the WRAs varied greatly between species, with 4 species removed from the analysis because the required number of questions in each section had not been answered.

RESULTS AND DISCUSSION

The WRA score values of the 54 quarantine weed species ranged from 16 to 35. Among these 54 species, 33 species showed high risk, 16 species showed intermediate risk and 4 species showed low risk. The highest WRA score (35) was recorded for the species *Senecio inaequidens* DC. The WRA scores for the 3 species namely *Centaurea diffusa* Lam., *Senecio jacobaea* L. and *Solanum carolinense* L. was observed to be 34. The WRA score of *Helianthus californicus* DC. and *Cichorium pumilum* Jacq. was 17 and 19, respectively. Whereas, the lowest WRA score (16) was observed in case of *Cichorium spinosum* L.

In Asteraceae, the WRA score ranged from 16 to 35 among the 17 species. The three species namely *C. pumilum*, *C. spinosum* and *H. californicus* were categorized into low-risk species whose WRA scores were 19, 16 and 17 respectively. On the other hand, two species namely *Chrysanthemoides monilifera* and *Conyza sumatrensis* showed intermediate risk and their scores were 26 and 23, respectively. All the remaining species in Asteraceae family were categorized into high-risk species (**Figure 1, Table 2**).

Among the 9 species weeds belonging to Poaceae the WRA scores ranged from 24 to 32. The four species namely *Cenchrus incertus*, *Lolium multiflorum*, *Oryza longistaminata* and *Urochloa plantaginea* were categorized into intermediate risk species, whose WRA scores were found to be 24, 26, 27 and 25 respectively. While five species namely *Apera spica-venti*, *Bromus secalinus*, *Digitaria velutina*, *Echinochloa crus-pavonis* and *Pennisetum macrourum* were categorized into high-risk species. No species of Poaceae family was categorized into the low-risk species category (**Figure 2**).

Despite advances of a structured post-border weed risk management system (Anon, 2006), its implementation has been limited to Australia (Auld 2012; Downey and Richardson 2016), although at a provincial level (Virtue 2010, Setterfield *et al.* 2010). In the present study we have made an attempt to evaluate the risk imposed by the Quarantine weeds, although these weeds have not been reported in India, their risk potential analysis can be used as source of information as well as post-border risk potential data in case these weeds if at all encountered at quarantine centers in India. Gordon *et al.* (2016) argued that cost–benefit analyses of weed risk should be conducted, regardless of their impact on strategic choices. The benefit of involvement is sometimes undervalued due to inadequate estimations of economic losses incurred due to invasive plant

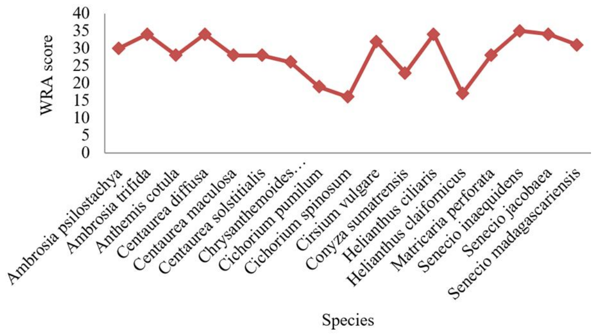

Figure 1. WRA score variation in Asteraceae family weeds

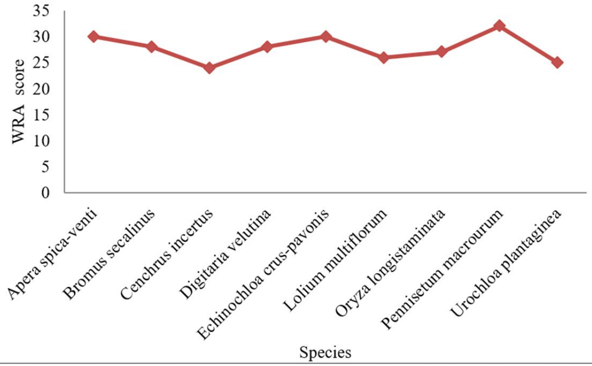

Figure 2. WRA score variation in poaceae family weeds

Table 2. Outcome of the weed risk assessment (WRA)

Sl. No.	Plant name	Family	Score	Risk level	Reference
1	*Alectra vogelii* Benth.	Scrophulariaceae	26	Intermediate risk	CABI
2	*Allium vineale* L.	Alliaceae	30	High risk	CABI
3	*Amaranthus blitoides* S. Wats.	Amaranthaceae	31	High risk	CABI
4	*Ambrosia psilostachya* D.C.	Asteraceae	30	High risk	CABI
5	*Ambrosia trifida* L.	Asteraceae	34	High risk	CABI
6	*Anthemis cotula* L.	Asteraceae	28	High risk	CABI
7	*Apera spica-venti* (L.) P.Beauv.	Poaceae	30	High risk	CABI
8	*Bromus secalinus* L.	Poaceae	28	High risk	CABI
9	*Cenchrus incertus* M.A.Curtis	Poaceae	24	Intermediate risk	CABI
10	*Centaurea diffusa* Lam.	Asteraceae	34	High risk	CABI
11	*Centaurea maculosa* Lam.	Asteraceae	28	High risk	Google
12	*Centaurea solstitialis* L.	Asteraceae	28	High risk	CABI
13	*Centrosema pubescens* Benth.	Fabaceae	22	Intermediate risk	CABI
14	*Chrysanthemoides monilifera* (L.) T. Norlindh	Asteraceae	26	Intermediate risk	CABI
15	*Cichorium pumilum* Jacq.	Asteraceae	19	Low risk	Google
16	*Cichorium spinosum* L.	Asteraceae	16	Low risk	Google
17	*Cirsium vulgare* Savi (Ten.)	Asteraceae	32	High risk	CABI
18	*Conyza sumatrensis* (Retz.) E. Walker	Asteraceae	23	Intermediate risk	CABI
19	*Cordia crassavica* (Jacq.) Roemer & Schultes	Boraginaceae	29	High risk	CABI
20	*Cuscuta australis* R. Br.	Convolvulaceae	23	Intermediate risk	Google
21	*Cynoglossum officinale* L.	Boraginaceae	28	High risk	CABI
22	*Digitaria velutina* (Forssk.) P. Beauv.	Poaceae	28	High risk	CABI
23	*Echinochloa crus-pavonis* (Kunth) J. A. Schultes	Poaceae	30	High risk	CABI
24	*Fallopia japonica* (Hout.) R. Decr.	Polygonaceae	30	High risk	CABI
25	*Froelichia floridana* (Nutt) Moq.	Amaranthaceae	20	Low risk	CABI
26	*Fumaria officinalis* L.	Papaveraceae	26	Intermediate risk	CABI
27	*Galium aparine* L.	Rubiaceae	28	High risk	CABI
28	*Helianthus ciliaris* DC.	Asteraceae	34	High risk	CABI
29	*Helianthus claifornicus* DC.	Asteraceae	17	Low risk	Google
30	*Heliotropium amplexicaule* Vahl.	Boraginaceae	33	High risk	Google
31	*Lolium multiflorum* Lam.	Poaceae	26	Intermediate risk	CABI
32	*Lonicera japonica* Thunb	Caprifoliaceae	30	High risk	CABI
33	*Matricaria perforata* (Mérat) M. Lainz	Asteraceae	28	High risk	CABI
34	*Orobanche cumana* Wallr	Orobanchaceae	28	High risk	CABI
35	*Orobanche minor* Sm.	Orobanchaceae	30	High risk	CABI
36	*Oryza longistaminata* A. Chev. & Roehr.	Poaceae	27	Intermediate risk	CABI
37	*Pennisetum macrourum* Trin.	Poaceae	32	High risk	CABI
38	*Polygonum lapathifolium* L.	Polygonaceae	26	Intermediate risk	CABI
39	*Proboscidea louisianica* (P. Mill.) Thellung	Martyniaceae	22	Intermediate risk	Google
40	*Pueraria montana var. Montana* (Lour.) Maesen	Fabaceae	30	High risk	CABI
41	*Raphanus raphanistrum* L.	Brassicaceae	32	High risk	CABI
42	*Richardia brasiliensis* Gomes	Rubiaceae	24	Intermediate risk	CABI
43	*Salsola vermiculata* L.	Chenopodiaceae	32	High risk	CABI
44	*Senecio inaequidens* DC.	Asteraceae	35	High risk	CABI
45	*Senecio jacobaea* L.	Asteraceae	34	High risk	CABI
46	*Senecio madagascariensis* Poiret	Asteraceae	31	High risk	CABI
47	*Solanum carolinense* L.	Solanaceae	34	High risk	CABI
48	*Striga aspera* (Willd.) Benth	Orobanchaceae	30	High risk	CABI
49	*Striga hermonthica* (Del) Benth	Orobanchaceae	32	High risk	CABI
50	*Thesium australe* R. Br	Santalaceae	19	Low risk	Google
51	*Thlaspi arvense* L.	Brassicaceae	26	Intermediate risk	CABI
52	*Urochloa plantaginea* (Link) RD Webster	Poaceae	25	Intermediate risk	CABI
53	*Veronica persica* Poir	Scrophulariaceae	23	Intermediate risk	CABI
54	*Viola arvensis* Murr.	Violaceae	26	Intermediate risk	CABI

species (Keller *et al.* 2007). In Indian perspective the current status of these developments is unknown, limiting broader adoption. Thus, our development of a WRA system for Quarantine weeds involving evaluation will make a significant contribution to future developments, testing and broader adoption of WRA systems in India.

Conclusion

The assessment of the WRA approach's significance depends mostly on the right outcomes and consideration of the time scale. In terms of invasive plants, if a country is risk-averse, the WRA strategy offers a conservative structure that can be used to determine risks and guide decision-making. A nation with a new plant species exploitation strategy may assume that relying on the WRA approach would lead to the rejection of plant species that could potentially provide economic benefits. Also in these situations, however, the WRA assessment can offer a valuable estimation of the possible consequences of introduction, adding to an informed consideration of the costs and benefits of a new species. The implementation of such programs will strengthen weed management decision-making, which can increase the ability of weed managers and scholars, which is crucial for enhancing the results of weed management in India. Countries like USA have standardized the processes for WRA and are being updated regularly (USDA 2019). India needs to finalize the processes to suit to Indian needs and update it regularly, to utilize the WRA for effective weed management decision-making.

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