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Pre-Import Invasiveness Screening of Plants for Planting Discussion Paper

Prepared by the Invasive Species Panel of the North American Plant Protection Organization (NAPPO)

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Table of Contents

Page

Issue

The importation of plants for planting creates multiple opportunities for the introduction of new invasive alien species, including invasive plants. Currently, however, Canada, Mexico and the United States, the three member countries of the North American Plant Protection Organization (NAPPO), do not routinely screen plant species intentionally imported for planting on the basis of their potential to be weedy or invasive. The NAPPO standard *RSPM No. 24: Integrated Pest Risk Management Measures for the Importation of Plants for Planting into NAPPO Member Countries*[1] focuses on plant pests (e.g., insects, diseases) that might be accidentally introduced through the plants for planting pathway, but does not address the risk posed by the plants themselves. Hence, there is a need for a regional standard that can guide NAPPO countries as they move forward to develop guidelines for pre-import screening of plants for planting, to reduce the risk of introducing new invasive alien plant species.

Introduction and Scope

The NAPPO Invasive Species (IS) Panel has been charged with establishing guidelines for pre-import risk assessment, or "screening", of new plants for potential invasiveness that can be proposed at an international level. The guidelines will not be a screening tool *per se*, and will not bind any member country to a particular methodology. Rather, they will provide a framework within which each country can develop its own system for screening plants for potential invasiveness.

The scope of the guidelines, and this discussion paper, will be the 'plants for planting' pathway (i.e. live plants and viable plant parts proposed for intentional import for planting and/or propagation). The scope does not include other potential pathways of invasive plant introduction, such as unintentional introduction of weeds as contaminants in seed shipments or intentional importation of plants for food or feed purposes.

Definitions and Acronyms

The definitions for phytosanitary terms and acronyms used in this document are taken, in order of priority, from: (1) ISPM No. 5, *Glossary of phytosanitary terms*[2], 2009, FAO, Rome; (2) RSPM No. 5, *Glossary of Phytosanitary Terms*, 2008, NAPPO, Ottawa; (3) the *McGraw-Hill Dictionary of Scientific & Technical Terms, 6th Edition* (McGraw-Hill, 2003), or (4) as indicated after the definition. Note that ISPM No. 5 (2009) includes *Appendix 1: Terminology of the Convention on Biological Diversity in Relation to the Glossary of Phytosanitary Terms*. Definitions provided in this Appendix are not IPPC definitions; rather they are CBD definitions with an explanation in the IPPC context. In such cases, both the CBD definition and the IPPC explanation are provided below, as indicated.

Alien species – CBD definition:	A species, subspecies or lower taxon, introduced outside its natural past or present distribution; includes any part, gametes, seeds, eggs, or propagules of such species that might survive and subsequently reproduce.
Explanation in IPPC context:	An alien species (CBD) is an individual or population, at any life stage, or a viable part of an organism that is non-indigenous to an area and that has entered by human agency into the area (1).
CBD	Convention on Biological Diversity (1).

[1] NAPPO standards, called RSPMs or Regional Standards for Phytosanitary Measures, are available on the NAPPO website at http://www.nappo.org/menu_e.shtml.
[2] IPPC standards, called ISPMs, or International Standards for Phytosanitary Measures are available on the IPPC website at https://www.ippc.int/IPP/En/default.jsp.

CFIA	Canadian Food Inspection Agency (2).
Epigenetics	The study of heritable changes in gene expression and function that can not be explained by changes in DNA sequences. The gene-expression states are stable and transmitted through cell division, which can be perpetuated in the absence of conditions that established them (Richards, 2006)
Fitness	A measure of reproductive success for a genotype, based on the average number of surviving progeny of this genotype as compared to the average number of other, competing genotypes (3)
Fynbos	A biome of southern coastal South Africa characterized by a diverse richness of endemic plant species (as of the heath, protea, composite, iris and lily families), by soil that is acidic and nutrient-poor, and by a climate marked by cold wet winters and hot dry summers ; *also* : the type of vegetation characteristic of this biome (Merriam-Webster, 2008).
Genotype	The genetic constitution of an organism, usually in respect to one gene or a few genes relevant in a particular context (3).
Inspection	Official visual examination of plants, plant products or other regulated articles to determine if pests are present and/or to determine compliance with phytosanitary regulations (1).
Invasive alien species CBD definition:	An alien species whose introduction and/or spread threaten biological diversity.
Explanation in IPPC context:	An invasive alien species (CBD) is an alien species (CBD) that by its establishment or spread has become injurious to plants, or that by risk analysis (CBD) is shown to be potentially injurious to plants (1).
IPPC	International Plant Protection Convention (1)
ISPM	International Standard for Phytosanitary Measures (1).
NAPPO	North American Plant Protection Organization (2).
Naturalized	Of a species, having become permanently established after being introduced (3).
Pest	Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products (1).
Pest risk (for quarantine pests)	The probability of introduction and spread of a pest and the magnitude of the associated potential economic consequences (1).
Pest risk analysis	The process of evaluating biological or other scientific and economic evidence to determine whether an organism is a pest, whether it should be regulated, and the strength of any phytosanitary measures to be taken against it (1).
Pest risk assessment	(for quarantine pests) – Evaluation of the probability of the introduction and spread of a pest and of the associated potential economic consequences (1).
Phenotype	The observable characteristics of an organism, dependent upon genotype and environment (3).
Phenotypic plasticity	The range of genotype expression in different environments (3).
Phytosanitary certificate	Certificate patterned after the model certificates of the IPPC (1).
Phytosanitary certification	Use of phytosanitary procedures leading to the issue of a Phytosanitary Certificate (1).
Phytosanitary measure	Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of quarantine pests, or to limit the

	economic impact of regulated non-quarantine pests (1).
Plants	Living plants and parts thereof, including seeds and germplasm (1)
Plants for planting	Plants intended to remain planted, to be planted or replanted (1).
PRA	Pest Risk Analysis (1).
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (1).
RSPM	Regional Standard for Phytosanitary Measures (2).
SAGARPA	Secretary of Agriculture, Livestock, Rural Development, Fish and Food (2).
Screening process	A risk assessment system designed to evaluate the invasive potential of a species prior to importation or introduction into a new ecosystem (Fraidenburg, 2002).
USDA-APHIS	United States Department of Agriculture – Animal and Plant Health Inspection Service (2).

Background

NAPPO recognizes that traditional phytosanitary measures (e.g., end product inspection, phytosanitary certification, and quarantine restrictions) are not always sufficient for reducing the risk of introducing new plant pests through the plants for planting pathway. A new NAPPO standard was developed to address this issue in part, and approved in October 2005. *RSPM No. 24 Integrated Pest Risk Management Measures for the Importation of Plants for Planting into NAPPO Member Countries, 2005, NAPPO, Ottawa* recommends an integrated approach based on best industry practices to reduce the risk of introducing plant pests through this pathway, without undue disruption to international trade.

However, the importation of plants for planting is also a significant pathway for the introduction of new invasive alien plants. Plants as pests were not considered within the scope of the new standard, and the risk of introducing new invasive alien plants through this pathway is not currently addressed.

In February 2006, the NAPPO Grains, Pest Risk Analysis (PRA) and IS Panels held a joint meeting in Ottawa, Canada, to discuss issues of common interest. A presentation on RSPM No. 24 initiated discussions on the need to address plants as pests (i.e., invasive alien plants) that might be introduced through the plants for planting pathway. The panels agreed that new plants should be screened for potential invasiveness prior to import, and that guidelines for screening should be developed by the IS Panel in consultation with the PRA Panel. These guidelines could then be used by countries to develop screening methods, and to support risk management decisions to allow or prohibit plants proposed for intentional importation, on the basis of their potential to be invasive species.

What is Screening?

The IS Panel discussed at length the meaning of the term “screening”. To some, screening is a pest categorization applied to a subject plant, in order to determine whether the plant meets the definition of a quarantine pest. This pest categorization may or may not lead to a full risk analysis. To others, screening is a risk assessment that leads to a decision about whether the plant should be imported, based on its potential to be an invasive species. To some others, screening is a specific form of risk assessment, consisting of a set of questions posed on a spreadsheet, where numbers are assigned and the plant is accepted or rejected based on a numerical score.

Most of the working group members agreed that "screening" is a form of risk assessment and agreed with the definition of "screening process" from a 2002 workshop held by the United States Aquatic Nuisance Species Task Force: "A risk assessment system designed to evaluate the invasive potential of a species prior to importation or introduction into a new ecosystem" (Fraidenburg, 2002).

Existing Regional and International Standards Relevant to Pre-import Invasiveness Screening of Plants for Planting

The following section summarizes the existing NAPPO and IPPC standards that are relevant to the discussion, and outlines the possible ways in which screening guidelines could be developed.

NAPPO Regional Standards for Phytosanitary Measures (RSPMs)

RSPM No. 24, Integrated Pest Risk Management Measures for the Importation of Plants for Planting into NAPPO Member Countries, 2005, NAPPO, Ottawa.

This standard identifies the importation of live plants for planting and/or propagation as a significant pathway for the introduction of new invasive alien plant pests. It recommends an integrated approach based on best industry practices to reduce the risk of pest introduction through this pathway, without undue disruption to international trade. However, plants as pests *per se* are excluded from the scope of the standard. Guidelines for screening plants as pests could potentially be developed as an appendix or annex to RSPM No. 24. However, it has been noted in previous panel discussions that the specific exclusion of plants as pests from its scope makes RSPM No. 24 an awkward platform for a discussion of screening methods.

IPPC International Standards for Phytosanitary Measures (ISPMs)

ISPM No. 2, Framework for pest risk analysis, 1995, FAO, Rome.

This standard provides a framework describing the pest risk analysis (PRA) process within the scope of the IPPC. PRA is used to characterize the risk associated with a quarantine pest and to evaluate management options to reduce the risk to an acceptable level. ISPM No. 2 introduces the three stages of PRA (initiation, risk assessment and risk management) and then focuses on the initiation stage. It also addresses generic issues of information gathering, documentation, risk communication, uncertainty and consistency.

ISPM No. 2 explicitly includes plants as pests within its scope, stating that: "When deliberately introduced and established in intended habitats in new areas, organisms imported as commodities (such as plants for planting, biological control agents and other beneficial organisms, and living modified organisms (LMOs)) may pose a risk of accidentally spreading to unintended habitats causing injury to plants or plant products. Such risks may also be analyzed using the PRA process." It also discusses plants as pests in more detail in section 1.2.1 "Plants as pests". Pre-import screening of plants for planting could be considered equivalent to the "risk assessment" stage of the PRA process in this context.

ISPM No. 11,Pest risk analysis for quarantine pests, including analysis of environmental risks and living modified organisms, 2004, FAO, Rome.

ISPM No. 11 provides specific guidance on PRA for quarantine pests. It provides detail for the conduct of PRA and describes the process to be used for both risk assessment and risk management. Risk assessment evaluates the likelihood of introduction of a pest into a given area, and the potential consequences if that introduction were to occur. Risk management considers the availability, feasibility, and cost-effectiveness of phytosanitary measures that may be used to reduce the pest risk to an acceptable level.

ISPM No. 11, like ISPM No. 2, explicitly addresses plants as pests, stating in *Annex 1: Comments on the scope of the IPPC in regard to environmental risks* that: "the full range of pests covered by the IPPC extends beyond pests directly affecting cultivated plants. The coverage of the IPPC definition of plant pests includes weeds and other species that have indirect effects on plants, and the Convention applies to the protection of wild flora". This Annex also states that environmental risks and risks to biodiversity should be analyzed through PRA. Other annexes to ISPM No. 11 include *Annex 2: Comments on the scope of the IPPC in regard to pest risk analysis for living modified organisms* and *Annex 3: Determining the potential for a living modified organism to be a pest*. Additional guidance on the specific case of pre-import risk assessment, or screening, of intentionally imported plants could potentially form the basis of another annex.

Discussion

An examination of the existing regional and international standards suggests that new guidelines for pre-import screening of plants for planting as pests may be most appropriately placed as an additional annex to ISPM No. 11. The process of determining whether an imported plant species is likely to become invasive (or a "pest") in a given area (the PRA area) is analogous to the "risk assessment" stage of the PRA process described in ISPMs No. 2 and No. 11, and an entirely new standard would contain a significant amount of duplication. Indeed, the IPPC has already begun to address plants for planting as pests within the text of ISPMs No. 2 and No. 11, by explicitly stating that the PRA process can be applied in those circumstances.

It is interesting to note that discussions about developing further guidance for screening plants for planting as pests are also ongoing at the IPPC level. A proposal has been advanced within the IPPC framework, with *Specification No. 44: Pest Risk Analysis for Plants as Quarantine Pests*[3], which was approved by the IPPC Standards Committee in May 2007. It proposed that a working group of 5-8 phytosanitary and/or plant pest (invasive alien plant) experts be formed to develop a standard that will "provide guidance to NPPOs in determining the pest potential of a plant, proposed for movement into an area where it is not yet present, to be regulated as a quarantine pest and other steps of a PRA, if appropriate". The standard will address only plants proposed for intentional import, and not invasive species unintentionally introduced in other commodities. While this sounds highly relevant to the work undertaken by the NAPPO IS panel, the IPPC working group has not yet been formed, and the process to do so is likely to take several years. However, it is of interest to note that Specification No. 44 states that the standard will be developed as "a new annex and, if appropriate, new supplemental text for the body of ISPM No. 11".

At the regional level, there are no North American (NAPPO) standards for PRA. The standards used by North American countries are those established at the international level (ISPMs No. 2 and No. 11). The NAPPO IS Panel therefore proposes that guidelines for screening plants for planting as pests be developed as a NAPPO RSPM, that could serve as a basis for the development of an annex to ISPM No. 11.

[3] IPPC Specifications are available on the IPPC website at https://www.ippc.int/IPP/En/default.jsp.

Current Regulatory Framework for Plants for Planting in NAPPO Countries

The International Plant Protection Convention (IPPC) has been designated by the World Trade Organization as the international phytosanitary standard-setting authority under which the signatory countries' regulatory frameworks should operate. Phytosanitary measures have been developed against the introduction and spread of pests in each country. Regulatory authority for the importation of plants in each country is based on national acts and regulations.
Proposals are at various stages of development within NAPPO member countries to implement measures for screening new plant species proposed for import for planting and/or propagation. The following section outlines the current (and in some cases proposed) regulatory framework for plants for planting in Canada, the United States, and Mexico.

Canada

Import requirements for plants (or plant products) proposed for importation into Canada have traditionally focused on their potential to be a pathway for entry of plant pests. Requirements have been developed, on the basis of pest risk analysis, to prevent unintentional introduction of plant pests such as insects, mites or pathogens, while permitting the intentional introduction of the desired plants. This model has more recently been adapted to address the potential pest risk presented by plants themselves. Pest risk assessments on plants to determine their potential as pests may be initiated for a number of reasons, including a request to import and cultivate a new plant species not previously known, or not widely present, in Canada; a new finding of a plant known to be invasive elsewhere and not previously known in Canada; or new information on increasing impacts of an invasive plant that has been recently introduced to Canada or is increasing in importance elsewhere and may be expected to occur in future in Canada. However, most plants are currently permitted entry without having been fully analyzed for their potential as pests, on the basis of the earlier tradition of policy development which focused on plant pests.

For those species that are determined to be of potential concern, weed risk assessment is conducted on the plant species of interest following the applicable IPPC standards for pest risk analysis (PRA). This process assesses the plant species' potential to be introduced and become established in Canada, the extent of its potential establishment, and the magnitude and nature of potential impacts of its occurrence. The pest risk management portion of the PRA determines whether or not the assessed risk is acceptable, and if not, what mitigation measures might be appropriate. Consultation with experts in various fields, including those in government, academia, and industry, and the general public is an integral part of the PRA process. At the conclusion of consultations, the PRA (including the risk assessment and risk management documents) provides the basis on which policy decisions are made.

Federal Regulatory Authority

The Canadian Food Inspection Agency (CFIA) is Canada's National Plant Protection Organization and is responsible for the administration of 14 Acts and their associated regulations. The CFIA may regulate plants for planting under the *Plant Protection Act* and *Regulations*, the *Seeds Act* and *Regulations*, and the *Feeds Act* and *Regulations*[4]. Additional federal legislation administered by Environment Canada has also been determined to be applicable to the issue of invasive alien plants, as detailed below.

In Canada, the *Plant Protection Act* provides authority to prevent the importation, exportation and spread of injurious or potentially injurious plant pests (including plants as pests). A plant may also

[4] Canadian Acts and Regulations are available on the Department of Justice Canada website at http://laws.justice.gc.ca/en/.

be listed as a noxious weed in the *Weed Seed Order* of the *Seeds Regulations*, also administered by the CFIA, where the presence of those weeds in imported and domestically traded seed commodities is prohibited. All imported seeds are subject to an import conformity assessment. Part V of the *Seeds Regulations* regulates the intentional release of seed into the environment. With some exceptions, notification and evaluation of the potential impact on, and risk to, the environment are required before a person can undertake either the confined or unconfined release of seed, including plants with novel traits (PNTs). The CFIA reviews applications for permits to import PNTs under the *Plant Protection Act.*

Environment Canada

Environment Canada is responsible for the *Canadian Environmental Protection Act* (CEPA) and the *New Substances Notification Regulations* (Organisms) [NSNR(O)]. CEPA regulation is intended to ensure that new organisms which are not covered under other scheduled acts are assessed for potential harmful effects. The NSNR(O) regulates new substances, including any new plant, before introduction into Canada. The NSNR (Schedule XIX) also assesses the invasiveness of new species intended for importation into Canada.

Environment Canada is also responsible for implementing the Convention on International Trade in Endangered Species of Wild Fauna and Flora (CITES). The import and export of certain plant species also must comply with CITES regulations. The convention regulates the international trade and movement of animal and plant species that have been, or may be, threatened due to excessive commercial exploitation.

Environment Canada's Canadian Wildlife Service (CWS) administers the *Wild Animal and Plant Protection and Regulation of International and Interprovincial Trade Act* (WAPPRIITA), which is the regulatory instrument for the implementation of CITES in Canada. The CFIA assists the CWS in processing documentation on artificially propagated plants already controlled through the *Plant Protection Act.*

Importation of Plants for Planting

The CFIA has a number of policy directives that govern the importation of plants for planting into Canada. Importation of rooted and unrooted plants and other propagative parts (e.g. cuttings, grafting plant material, specialized stems and root structures), including tissue-cultured material intended for planting, from all origins is regulated. In addition, plants from all origins except the continental United States require a permit to import. However, it should be emphasized that most current regulations address the risk of pests that may be associated with a commodity, rather than the risk posed by the commodity (plant species) itself.
The CFIA directive *D-02-02: Plant Protection Import Requirements for rooted, or unrooted plants, plant parts, and plants in vitro for planting*[5], contains the general import requirements for plants and plant parts for planting from all countries to prevent the entry and spread of quarantine pests into Canada. The intent of this directive is to provide an overview of the main plant protection requirements that Canadian importers and foreign exporters must comply with prior to importing plant material to Canada. Shipments of plants are required to be free of regulated pests and may also be subject to additional requirements depending on their country of origin and their species. For example, all soil and related matter, whether in association with plants, or alone, is prohibited entry into Canada from all countries other than non-regulated areas of the continental US.

The importation of rooted plants from outside the continental US with soil or soil-related matter is prohibited. A permit to import and phytosanitary certificate are required for the import of rooted

[5] CFIA directives are available on the CFIA website at http://www.inspection.gc.ca/.

plants from outside the continental US without soil (unrooted) or rooted in growing medium when grown in facilities approved under the Canadian Growing Media Program (CGMP). Shipments of unrooted plants, or plants rooted in soil or related matter from the continental US do not require an import permit (unless otherwise indicated), however, they do require a phytosanitary certificate with appropriate additional declarations.

The United States

The United States regulates plants for planting under authority of the *Plant Protection Act*, the *Federal Seed Act*, and the regulations under these Acts[6]. Under the *Plant Protection Act*, the Secretary of Agriculture is authorized to undertake such actions as may be necessary to prevent the introduction and spread of plant pests and noxious weeds within the United States. The Secretary has delegated this responsibility to the Administrator of the Animal and Plant Health Inspection Service (APHIS), which is the National Plant Protection Organization for the United States.

The regulations in Chapter 7 of the Code of Federal Regulations (CFR), part 319 (foreign quarantine notices) prohibit or restrict the importation of certain plants and plant products into the United States to prevent the introduction of plant pests that are not already established in the United States or plant pests that are established and under official control in the United States. The regulations in "Subpart—Nursery Stock, Plants, Roots, Bulbs, Seeds, and Other Plant Products," 7CFR 319.37, restrict, among other things, the importation of living plants, plant parts, seeds, and plant cuttings for planting or propagation. The regulations in 7 CFR part 360, “Noxious Weed Regulations,” contain restrictions on the movement of noxious weeds or plant products listed in that part into or through the United States and interstate; the importation of some plants is subject to both the nursery stock regulations and the noxious weed regulations.

Plants intended for planting do not currently require invasiveness screening prior to import. No formal request for importation is required, except for plants currently prohibited or plants established in growing media. Most plants for planting are allowed to be imported if accompanied by a general import permit and phytosanitary certificate from the exporting country and after inspection at a Federal plant inspection station at the port of entry.

Currently, under the nursery stock and noxious weed regulations, the entry of plants for planting is prohibited or restricted only after a pest risk analysis is performed to determine the sources of pest risk and appropriate mitigations and subsequent notice-and-comment rulemaking are completed. Over 100 host plant taxa are prohibited from specific geographical locations based on pest association; 94 taxa are regulated as Federal noxious weeds. APHIS modifies the lists through rulemaking to establish or relieve restrictions based on experience, a pest risk analysis, or other information indicating a change in the status of pest threats.

In the United States, the *Plant Protection Act* authorizes APHIS, in an emergency situation, to take administrative action to prohibit or restrict the entry or subsequent interstate movement of a taxon of plants for planting if it poses an immediate danger of introducing or spreading a plant pest or noxious weed in the United States. In such an emergency situation, rulemaking may be completed after the prohibition or restrictions are imposed.

The noxious weed regulations are separate from the nursery stock regulations and contain restrictions on the movement of listed noxious weeds into, within and through the United States. To add a plant to the list of noxious weeds, or to remove a plant from that list, APHIS conducts a comprehensive pest risk analysis. This analysis includes the dispersal potential and environmental

[6] United States Regulations are available on the electronic Code of Federal Regulations website at http://ecfr.gpoaccess.gov/cgi/t/text/text-idx?c=ecfr&tpl=%2Findex.tpl.

impacts of the plant, which evaluate the potential of the plant to be an invasive species. (The term *invasive species* is defined by Executive Order as a species that is: (1) Non-native (or alien) to the ecosystem under consideration and (2) whose introduction causes or is likely to cause economic or environmental harm or harm to human health.) If the pest risk analysis indicates that the plant under consideration poses a high pest risk, APHIS undertakes rulemaking to add it to the noxious weed list.

Revision of the U.S. Regulatory Framework for Plants for Planting

APHIS is now engaged in a comprehensive review and modernization of the nursery stock regulations. One of the first regulatory initiatives is to establish a new category of regulated articles, plants for planting whose importation is not authorized pending pest risk analysis (NAPPRA). In order to determine whether to add a taxon of plants for planting to this category, APHIS would review available scientific information and apply a simple screening process, which consists of determining the accepted name of the species, its distribution, and evidence of harm. If the scientific information indicates that the taxon of plants for planting is a potential quarantine pest, APHIS would then publish a notice of the intention to add the taxon to the proposed NAPPRA category.

To remove a plant from the new category, APHIS would conduct a pest risk analysis at the request of an exporting country's plant protection organization. The results of the pest risk analysis would determine whether the taxon would be listed as a Federal noxious weed or removed from the proposed category and allowed to be imported subject to general requirements. A PRA process incorporating a form of invasiveness screening will be needed to evaluate NAPPRA taxa in a timely manner, and will be needed for the long-term goal of the nursery stock regulation revision – that eventually all unprecedented imports will be subject to a streamlined risk analysis which includes an invasiveness screening.

To support the revision of the nursery stock quarantine, the USDA, APHIS, Center for Plant Health Science and Technology (CPHST) is currently revising the USDA's weed risk assessment guidelines and conducting experimental studies of plants traits associated with invasiveness. In Raleigh, North Carolina, CPHST is revising the weed risk assessment (WRA) guidelines to incorporate results from recent work in invasive plant screening studies. One of the goals of the revision is to streamline the risk assessment process by incorporating different levels of analysis that would be used depending on the need and level of uncertainty. The predictive ability of the new WRA systems will be evaluated by testing it on a set of known invasive and non-invasive species in the United States.

In Fort Collins, Colorado, CPHST scientists are developing predictive models that use experimentally derived data on growth, performance, epigenetics, and phenotypic plasticity. Results from this study will identify traits that can be incorporated into a risk assessment system as described above, but it will also develop experimental methodologies for assessing plants requiring more detailed analysis, beyond that done in a WRA based on a literature review (See the appendices for additional information).

Mexico

Phytosanitary Regulatory Framework

Mexico regulates the importation of propagative material in accordance with the *Federal Plant Health Law*. The law states that the Ministry of Agriculture, Livestock, Rural Development, Fisheries and Food (SAGARPA) shall apply this law. SAGARPA has designated the National Service of Agri-food Health, Safety and Quality (SENASICA), as a decentralized administrative entity which is responsible for, among other things, regulating and monitoring plants, plant products, and by-products imported to, moved or exported from the national territory, and ensuring that they do not pose a phytosanitary risk. Therefore, the *Federal Plant Health Law* authorizes the corresponding official staff to undertake acts of authority.

SENASICA has delegated the plant health authorities to the Plant Health General Directorate (DGSV). This General Directorate is the National Plant Protection Organization authorized to establish phytosanitary measures to prevent the introduction, establishment and spread of plant pests, and plant products or by-products which may pose a phytosanitary risk.

Phytosanitary requirements for importation of propagative plant material including seeds for agricultural use are based on a pest risk analysis, taking into account quarantine pests related to the import pathway and the country of origin. These requirements as well as those for re-exportation are covered in the Official Mexican Standard NOM-006-FITO-1996, that establishes the minimum requirements applicable to general situations for plants, their products and byproducts that are intended for import when they are not already established in a specific Official Standard.

This scheme allows for evaluation of the risk posed by quarantine pests related to a commodity at the specified origin; however, the evaluation does not identify the potential for an imported plant species to become a quarantine pest or an invasive species.

The Official Mexican Standard NOM-007-FITO-1995, *Phytosanitary requirements and specifications for the importation of propagative plant material*, establishes the phytosanitary requirements based on a Pest Risk Analysis, for the importation of propagative plant material (except botanical seeds and forest species) in order to prevent the introduction, establishment and spread of exotic pests or pests of quarantine importance. The following propagative materials are subject to the provisions set by this standard: trees, shrubs, plantlets, bulbs, corms, roots, rhizomes, stems, tubers, scions, cuttings or budwoods, vine shoots, buds, plants for grafting, grafts, layers, in vitro crops and other material used for propagation; as well as its packing and packaging material. All propagative material imported is subject to a compliance check at the point of entry to Mexico.

When there is a request to import propagative plant material of a specific product not indicated in the above mentioned standard, the interested party may request to DGSV the phytosanitary requirements. Based on Article 24 of the *Federal Plant Health Law*, if there are authorized phytosanitary requirements to permit the importation of the required product, a phytosanitary requirement form (form SENASICA-02-22) will be issued which indicates the phytosanitary measures applicable to importations. The SENASICA website has an "On-line Consultation System for Phytosanitary Requirements", where you can find the phytosanitary requirements established by Mexico to permit the importation of plants, plants products and by-products.

To prevent the spread and introduction of weed species of quarantine importance, Mexico has established the Official Mexican Standard NOM-043-FITO-1999, *Specifications to prevent the introduction to the country of quarantine weeds*. This standard requires imported propagative material to be free from the species indicated in this regulation.

Environmental Regulatory Framework

The application of the *General Law on Ecological Balance and Environmental Protection* corresponds to the Secretariat of Natural Resources and Environment (SEMARNAT).

For wild species imported for exploitation (i.e. for Unidades de Conservación, Manejo y Aprovechamiento Sustentable de la Vida Silvestre (UMAS)), the *General Law on Ecological*

Balance and Environmental Protection (art 82, 85, 86 and 87), which regulates the protection and restoration of the ecological balance and the protection of the environment, considers the establishment of measures to regulate or restrict totally or partially the importation of flora specimens and their domestic movement or transit from other counties; the preservation and exploitation for economic activity; and the controlled reproduction of these species to avoid their spread. This act applies to possession, administration, preservation, re-population, propagation, importation, exportation and development of wild flora and fauna, as well as its genetic material, without prejudice to other legal orders.

It also establishes SEMARNAT's responsibility to request and issue technical opinions regarding environmental impact studies related to the introduction of new species, to ensure these species do not affect native populations, ecosystems and other species. Therefore, the General Wildlife Law, which establishes responsibilities for different government levels regarding sustainable conservation and exploitation of wildlife and its habitat, according to Art 9° XIII, makes the SEMARNAT responsible to issue, suspend and revoke authorizations and administer acts related to conservation, movement, importation, exportation and domestic transit of wildlife, as well as the importation of wildlife specimens, parts and by-products.

Forestry Regulatory Framework

The application of the *General Act for Sustainable Forestry Development* also corresponds to the Secretariat of Natural Resources and Environment (SEMARNAT).

The *General Act for Sustainable Forestry Development* regulates and promotes conservation, protection, restoration, production, organization, development, management and exploitation of the country's forestry ecosystems and their resources, as well as the distribution of authority related to forestry issues that correspond to the Federation, the States, Federal Districts and the Municipalities. According to this Act, the Federation is responsible to issue the certificates and other phytosanitary documentation for importation of forestry raw material and products, to monitor that the forestry industry's activities are consistent with the act, to issue the norms that establish exotic forestry plant species that pose a risk to the biodiversity and monitor the environmental impacts.

Current Weed Risk Assessment Methods Used in NAPPO Countries

This section of the discussion paper summarizes current methods and limitations of weed risk assessment in North America.

Comprehensive Weed Risk Assessments

USDA-APHIS and the CFIA use similar qualitative methods to evaluate the likelihood and consequences of introduction of weeds and invasive alien plants. These evaluations are based on IPPC guidelines and are usually triggered by the interception or unintentional introduction of a pest, or by a change in policy regarding a pest. They could also be used for plants for planting, to assess the invasive potential of a plant in response to an import request. The weed risk assessments involve comprehensive literature review and cover the main elements of initiation (initiating events, previous risk assessments, and description of the weed), and assessment (geographic and regulatory status, habitat suitability and establishment potential, spread and dispersal potential, potential economic and environmental impacts, and the likelihood of introduction). Criteria are discussed and then ranked as negligible, low, medium or high, and assigned scores ranging from zero to three, respectively, based on established guidelines. An overall rating is determined using a table that combines the outcomes of the likelihood of introduction and the consequences of introduction. Methods of weed risk assessment used in Mexico are similar to those used in the United States and Canada. Mexico uses pest risk assessment guidelines contained in ISPM No. 11

to perform risk assessments on insects, pathogens and weeds. Pest risk assessments on weeds therefore cover the same elements as those performed by the United States and Canada.

Current weed risk assessment methods used in the United States, Canada and Mexico provide a clear and thorough description of the risks and uncertainty associated with the potential introduction of a species, from which management and regulatory decisions can be made. These methods are transparent and consistent with IPPC guidelines. They also permit consideration of unique information or circumstances that a scoring system would not, and written justifications of the ratings allow for flexibility in assigning those ratings (Daehler and Denslow, 2007). None of the other methods discussed in this paper include a descriptive assessment of potential economic and environmental impacts.

However, for the purpose of screening plants for planting as pests there are a number of drawbacks to the weed risk assessment methods currently used by NAPPO member countries. For instance, success and failure rates at identifying invaders and non-invaders have never been tested (Daehler and Denslow, 2007). Predicting the potential range of an invasive species in the country of interest also remains a weakness for assessing habitat suitability or establishment potential. Furthermore, likelihood of introduction is an element of these weed risk assessments that is unnecessary for plants proposed for import. Most importantly, existing methods are extensive and time consuming, and result in documents that are generally at least 30 pages long and take several weeks to several months to complete. As a result, they are costly and impractical for screening large numbers of plants for planting.

Categorization

In addition to comprehensive weed risk assessments, Canada, the United States, and Mexico all currently use some kind of pre-risk assessment screening, or categorization, in the form of a quick series of questions to evaluate whether a full risk assessment is necessary. These categorizations are described in ISPM No. 11 as the preliminary stage of a pest risk assessment. They can be used to establish whether or not a taxon meets the criteria of a “quarantine pest”, i.e. it is absent from the risk assessment area (or present but not widely distributed and under official control), it has the potential to establish and spread, and it has the potential to cause economic harm within the risk assessment area. These criteria typically take the form of 3-4 questions to determine whether the taxon should be further evaluated as a quarantine pest: Does the species already occur in the PRA area? Could it potentially survive there? (e.g., climatic suitability) Has it been reported anywhere else as invasive or weedy? Questions can be answered in a “decision tree” structure; so each question either ends the assessment, or leads to the next (e.g., does the species already occur in the PRA area? If so, the assessment stops here. If not, go to question 2, and so on). In this way, the assessments are deliberately kept brief.

Categorization can be particularly useful for screening out low-risk or other non-quarantine species, for which no further evaluation is necessary. However, according to ISPM No. 11, the pest risk assessment process should continue beyond the categorization stage if the species is a potential quarantine pest or when there is insufficient information to make a determination. Species that are not screened out are therefore subject to the full weed risk assessment. Therefore, due to potentially large numbers of species that would still require full risk assessments, a categorization method such as described here would still be impractical as a pre-import screening tool for assessing plants for planting.

The question "Is it a weed elsewhere?" is considered one of the most useful predictors of invasiveness (Reichard and Hamilton, 1997; Gordon et al., 2008a; NRC, 2002) and could be classified as a type of categorization or quick screening system as well. Gordon et al. (2008a) for example, found that this criterion resulted in a 92% correct rejection rate for major invaders and 92% correct acceptance rate of non-invaders on a set of 158 alien plants in Florida. Two-thirds of minor invaders were rejected, and one third, accepted. Daehler et al. (2004) also examined the usefulness of this single criterion. For species of Hawaii and the Pacific Islands, it allowed entry of a greater number of major pests than other systems tested, although it was effective at admitting most non-invaders. This simple criterion for invasiveness has proven important as a component of larger weed risk assessment and screening tool systems. On its own, however, it has some serious limitations, including the fact that it does not consider the biological characteristics or the climatic suitability of the species in the proposed area of introduction. It also fails to consider that not all species have had the opportunity to become weedy elsewhere. Rapoport (1998) estimates that 85% of potentially invasive plants fall into this category.

Predicting Plant Invasiveness

This section of the discussion paper reviews recent literature on predicting plant invasiveness.

The success of a screening tool will be dependent upon its ability to predict whether or not an introduced plant will become invasive. The variables used to predict plant invasiveness can be placed under three general categories: those related to the species' biology, those related to the external environment, and those related to history of invasion and associated impacts (if known). Recent advances from the literature on the effectiveness of these types of variables for predicting plant invasiveness are discussed below. The development of accurate predictive models for plant invasiveness would be economically advantageous, when compared to the high cost of controlling rapidly spreading infestations (Finnoff et al., 2007).

Biological traits

Baker (1965, 1974) compiled a list of biological traits for the "ideal weed" including rapid development, high fecundity, readily dispersed seeds, broad climate range limits, and high phenotypic plasticity. These plant traits were verified as biological predictors when later chronicled in literature and in compilations of the world's most invasive plants (Mack, 1996). However, these generalized plant variables have yet to be translated into a suite of specific parameters that are common to all invasive plants.

Whether or not there are "universal" or "unique" plant traits that are associated with plant invasiveness is open to debate. Several invasive plant ecologists believe that there are as many reasons for plant invasiveness as there are invasive plants, i.e. each invasive plant has a unique or idiosyncratic set of invasive traits or properties (Williams et al., 2002; Williamson, 1999; Davis, 2006). A variation of the theme that each invasive plant has unique invasive properties is that there may be underlying biological mechanisms associated with invasiveness but the relationships between external plant conditions, internal plant traits and invasiveness are so complex that simple, streamlined models are an impossibility. Models that are limited to a specific life form, such a pines or woody shrubs, seem to generate more accurate results than broad-based models that try to combine several life forms (Grotkopp and Rejmanek, 2007). There seems to be a general consensus that research to date has not yet been able to discover a common set of underlying biological mechanisms that can accurately predict whether an unknown exotic species has a high potential for invasiveness after importation into a country (Mack et al., 2000). Current research has met with mixed results in attempting to understand and experimentally test relationships between biological mechanisms and plant invasiveness.

Some progress has been made by comparing biological parameters between related invasive and non-invasive plants. In some cases, invasive species have exhibited higher fecundity, relative growth rates, specific leaf area and resource use efficiencies than phylogenetically related non-invasive species (Burns, 2004; Garcia-Serrano et al., 2005; Grotkopp and Rejmanek, 2007; Pysek and Richardson, 2007). However, such differences are not always observed (Bellingham et al., 2004). Invasive plants may be opportunistic and express higher growth rates in high resource environments, revealing a possible biological explanation for their invasiveness. However, many invasive plants are also successful in colonizing resource-poor environments, which suggests that some invasive plants have higher resource-use efficiencies (Funk and Vitousek, 2007).

The effects of resource gradients and resource-use efficiencies are currently in the forefront of physiological research on invasive plants. A hypothesis for much of the resource gradient-based invasive plant research is that greater phenotypic plasticity allows invasive plants to be more adaptable, or have greater fitness, across diverse environments (Bossdorf et al., 2005; Sultan, 2003). Funk and Vitousek (2007) suggest that the advantage of resource-use efficiencies for invasive plants may be short-lived, and long-term effects should be studied. Long-term invasion dynamics may involve multiple biological mechanisms including: rapid adaptation to high-resource environments, resource-use efficiency, and other biological mechanisms such as allelopathy, adventitious root/shoot allocation, salt tolerance, fire tolerance, etc.

A literature review revealed that at least 13 recent studies compared selected biological parameters between invasive and non-invasive plants, and six of these studies involved resource-gradient experiments with water, light, temperature, and CO_2. The overall results are mixed, with invasive plants showing life stage and trait-specific plasticity, i.e. evidence of plasticity in gas exchange (Ewe and da Silveira Lobo Sternberg, 2005; Wilson et al., 2004), water-use efficiency (Brock and Galen, 2005; Xiong et al., 2004) and nitrogen-use efficiency (Niinemets et al., 2003; Durand and Goldstein, 2001), but fixed responses for other biological parameters (Brock et al., 2005; Ewe and da Silveira Lobo Sternberg, 2005).

The interaction between a genotype and the environment (genotype x environment = phenotype) determines the phenotype response to changes in the environment. As the above interaction implies, the fitness of a genotype conditioned to an environment is expressed in the limits of phenotypic plasticity (Bradshaw, 2006). The adaptability of a species, through phenotypic plasticity, genetics, or epigenetic mechanisms, should be highly correlated with its invasive potential, i.e. adaptability would be a primary predictor for invasiveness. The fluidity of genotypes over time has been highlighted in recent research involving hybridization, ploidy genetics, multiple-origin cross breeding, and epigenetics (Bossdorf et al., 2005; Perez et al., 2006). Genetic variability in plants over time is a major avenue of current research and is already yielding valuable insights into why certain species eventually become invasive.

Recent genetic research suggests that there is a correlation between ploidy levels, increased genetic diversity, and environmental adaptability of plant species (Hansen et al., 2007; Saltonstall, 2002). There are several well known exceptions to this generalization, including Japanese knotweed and alligator weed which are self-pollinating and have little genetic variation (Ward et al., 2008). Invasive plants with high adaptability traits may also have a diverse genetic base, or can be genetically traced to multiple origins (Clements et al., 2004; Clevering et al., 2001). The propensity of many invasive plants to hybridize, adapt to new environments through phenotypic plasticity, or adapt through epigenetics generally increases their aggressiveness and fitness traits and expands their ecological range limits.

With few exceptions (Grotkopp and Rejmanek, 2007) most of the above mentioned studies involved very few species and their non-invasive congeners. Thus extrapolation of their results to broader classification models, based on taxonomy or life form, is extremely limited. However, the majority of these studies indicate that biological parameters can be used to differentiate non-invasive from invasive plants, given the caveat that critical parameters usually vary among species and life stages. This suggests that a comprehensive suite of biological parameters, collected from different life stages, life forms, and over a range of resource gradients would be appropriate for developing a key component of predictive, science based models. Multivariate analysis could be used to analyze this information to assess the importance and strength of relationships between biological parameters and plant invasiveness (see Appendix 1).

Advantages and disadvantages of models based on biological traits

The basic premise for models based on biological traits is that there are underlying biological/genetic plant mechanisms that have detectable patterns or parameters that are common among invasive plants grouped under selected life forms, i.e. grasses, forbs, pines, etc. The primary advantage of such models is that they would be based upon underlying biological mechanisms or traits that are consistently and highly related to plant invasiveness. Assuming that the potential for invasiveness is a function of internal plant traits and environmental variables, then an integrated series of biological and climate models may achieve a high accuracy in predicting plant invasiveness. The basic relationships between biological traits and parameters and invasiveness offer an explicit “why” some plants become invasive and others do not when introduced to new environments. Another potential advantage is that poorly known plants classified for further evaluation may only require minimal collection of biological parameters, followed by reclassification using the appropriate models. Finally, biological models combined with spatial/climate models offer a science-based, transparent and defendable justification for denying the importation of plant species with a high potential for invasiveness.

The primary potential disadvantage of biological models is that the underlying biological mechanisms may not show consistent or universal relationships with plant invasiveness. A universal set of biological traits has yet to be established. A variation of this premise is that the relationships may be so complex and varied that general models are impossible to develop or have low predictability for invasiveness. Another potential disadvantage is that expensive and time consuming experiments may be necessary to test the responses of taxonomically-paired, non-invasive and invasive plants over a range of resource gradients. A major assumption that such expensive experiments are necessary is that there is no genetic trait that is universally correlated with all invasive species. If genetic traits are shown to govern the adaptability of a species, then inexpensive genetic tests can be developed for rapid classification of species with unknown biological traits. Although the surge in interest about the relationship between genetic variability and plant invasiveness is important, the basic interactions between plants and their environment should not be ignored but included in a comprehensive approach for predicting invasiveness (Perez et al., 2006; Chun et al., 2007).

Climate matching and spatial models

In addition to biological attributes, the invasive ability of plants is partially a function of abiotic and biotic environmental conditions where a species could survive, establish, and even spread over the landscape. The characteristics of the environment including soil properties, climate, and interaction with native vegetation and pests are all variables that may be highly associated with a species' invasive potential. A useful approach for predicting future distribution ranges for a plant species is to compare the environmental conditions of its native range with those of a potential habitat, i.e. climate matching with its indigenous range. This spatial modeling approach may be accurate when the indigenous or naturalized range of a plant is known. The basic premise of climate matching or spatial modeling is that external conditions such as climate, soils, or native vegetation can be used to model the ecological amplitude or range limits and/or predict the future distribution of an invasive species.

Numerous climate-based programs such as CLIMEX, BIOCLIM, and GARP have been developed to provide geographic assessments for potential distribution or predicted range limits for a species. For example, the climate matching program CLIMEX was developed to predict the potential geographic distribution for any invasive taxa (Sutherst et al., 1999). The meteorological database for CLIMEX includes 2500 global locations providing mean monthly temperatures, relative humidity, and rainfall. There are two modes in CLIMEX including; 1) Match Climates and 2) Compare Locations. The Match Climates program matches meteorological conditions among locations, while the Compare Locations program is used to predict potential distributions under current climate conditions. These predictions are based on either experimentally determined tolerances, life history of a species, or climatic variables in the native range of a species. A similar program has been developed by USDA-APHIS entitled NCSU-APHIS Plant Pest Forecasting (NAPPFAST) for pest risk mapping within the agency (Magarey et al., 2007). Climate-based models have become more complex and more specialized to meet the needs of government agencies or objectives of a project. For example, these models may be used to examine potential species ranges under different scenarios of climate change.

In addition to climate-based programs, there is potential for advancements in Geographic Information Systems (GIS) mapping techniques to contribute to predicting the potential distribution of introduced species. GIS technology has advanced so that soil properties, aerial photograph images, and weather and other spatial attributes can be layered onto invasive-plant survey maps. For example, the United States Natural Resource Conservation Service has soil maps for 95% of the counties in the USA that can be layered onto a GIS map. Furthermore, within the next six to 12 months the United States Geological Survey (USGS) will be able to provide archived weather and vegetation data collected by NASA satellites for any global site, with a resolution of one square kilometer. It will soon be possible to have detailed GIS maps layered with aerial photos, soil properties, and weather attributes, combined with multiple attributes assigned to each invasive plant infestation. Global Positioning System (GPS) units with submeter accuracy can be used in early detection surveys and would allow managers to rapidly estimate expansion rates.

Advantages and disadvantages of climate matching and spatial models

The primary advantage of GIS mapping and spatial modeling is that distribution maps with color coded probability levels can be developed for any species, given a survey dataset from an existing set of plant populations. As a result, questions regarding climatic suitability of a species in the potential area of introduction can be addressed with greater certainty. Critical source areas for new invasive species can also be identified (Thuiller et al., 2005). These methods also have the potential for providing "real time" maps showing the spatial and temporal dynamics of invasive-species distributions. Advances in GPS and GIS technology allow detailed maps with embedded attributes for weather and native vegetation. Internet-based programs enable government agencies, volunteer organizations, and citizen scientists to monitor, survey, model and map species distributions, which is a major advance towards "real time" maps. Spatial models are scalable from local to national landscapes, and multiple model results can be evaluated and compared for fitness and accuracy for a single analysis.

A disadvantage of spatial modeling is that only external factors are used to model/predict the relationships between invasive plants and their environment. Another primary disadvantage is that "predictive" spatial modeling is based on survey information from species that are already present within the USA. Predictive modeling for plant invasiveness should include an integrated, module based system with spatial and biological systems so that external and internal predictors are combined for enhanced accuracy. Another disadvantage is that other complex variables such as unpredictable dispersal/pathway conditions (Davis et al., 1998; NRC, 2002), random man-made or natural disturbances, abnormal weather conditions, propagule pressure, hybridization, or unpredictable interactions with native vegetation, insects, and diseases (Mack, 1996; NRC, 2002) also affect the spread rate and eventual range limits of a species. Models based solely on environmental factors cannot take into account the fact that limitations imposed by biotic factors in a species' native range (e.g. disease, herbivory, competition) are often lacking in the species' introduced range. Also there are several studies that show invasive plant range limits have exceeded the limits in their native ranges (e.g., Warwick et al., 1984).

Invasion history and associated impacts

According to international standards, an assessment of pest risk includes both an evaluation of the probability of the introduction and spread of a pest as well as an evaluation of the magnitude of associated potential economic consequences. For plants for planting, introduction is almost a certainty if the import permit is granted. Spread potential can be evaluated using the biological and environmental traits described above. For potential economic consequences, evidence from a plant's behaviour in both native and non-native environments and the associated economic impacts will lend weight to the assessment of pest risk in a new area. The same should be the case for a potential screening tool, although it is recognized that in some cases this information may not exist and not all species have had the opportunity to become weedy elsewhere (see discussion on "Is it a weed elsewhere?" on page 18). Overall, questions related to a species' invasion history and potential for economic impacts can provide powerful criteria for a screening tool or other pest risk assessment but would be insufficient on their own.

Screening Tools

This section of the discussion paper analyzes existing screening or assessment tools for predicting potential invasiveness of plants for planting. The various approaches are examined with regard to their relative strengths and weaknesses, as well as their usefulness and applicability in a North American context.

Screening tools require specific inputs for predicting plant invasiveness. These inputs, reviewed above, may be specific biological attributes of the species, characteristics of the external environment that it inhabits, or descriptions of the species' history of invasion and the types of impacts that can result. The inputs used in a model may be selected by using expert opinion, by multivariate analysis, or by expert systems that bring together both approaches (see Appendix 1). In general, the screening tools described in this section incorporate more than one type of input and use question-and-answer or decision-tree approaches. The result may be a numerical score, which is assessed along a scale of non-invasive to invasive, or a decision, such as deny or allow entry. An additional result may be that the species requires further evaluation. In systems that assign points for climatic suitability and plant attributes, the cut-off points for "accept, reject and evaluate further" must be defined.

The desired outcome of a screening tool is to reject a high proportion of invasive plants and to accept a high proportion of non-invasive plants. An assessment tool with a high error rate will misclassify and exclude many non-invasive species for every invasive species whose introduction it prevents (Keller et al., 2007). To test the results from invasiveness screening tools for a defined geographical area, researchers use the tools to evaluate plants that are both known invaders and known non-invaders in that area. The percent of test species that are correctly predicted, i.e., the successfulness of the tool, may depend on how the term "invader" is defined. Sometimes plants that are naturalized but not known to be negatively affecting agriculture or the environment have been categorized as "minor invaders" and lumped in with major invaders, which can affect the accuracy of prediction results (Gordon et al., 2008b). A risk assessment tool with a described accuracy rate of 90%, for example, may be significantly less accurate if calibrated using only plants that are "invasive", defined to include evidence that the species causes environmental or economic harm.

The following is a summary of the major screening tools in use around the world. Strengths and weaknesses of each screening tool are discussed using seven criteria: (1) Ability to discriminate between weeds and non-weeds; (2) Testing and validation; (3) Adaptability to different climates / ecosystems / growth habits; (4) Cost-effectiveness (ease of use, time required); (5) Scientific basis; (6) Objectivity; and (7) Ability to deal with knowledge gaps.

Reichard and Hamilton model (Reichard and Hamilton, 1997)

Reichard and Hamilton (1997) developed a decision tree that evaluates invasive potential based on woody plant traits. Specific elements of the decision tree relate to history of invasion elsewhere, taxonomic relationships with other invasive species, vegetative reproduction, native range, length of juvenile period, requirement for seed pre-treatment for germination, and whether or not the taxon is an interspecific hybrid. Information for using the decision tree can be gathered from the literature and herbarium specimens, or from experience cultivating the plant. The decision tree divides species into three categories: admit, deny admission, or delay admission (= evaluate further).

Of the specific elements of the decision tree, the single most reliable predictor was whether or not the species was known as an invader elsewhere in the world. Prediction was still possible, though with reduced success, based solely on biological and geographical attributes.

Ability to discriminate between weeds and non-weeds: The Reichard and Hamilton model rejected 85% of invaders, accepted 2%, and recommended further analysis for 13%. It accepted only 46% of non-invaders, rejected 18%, and recommended further analysis for 36%.

Testing and validation: Two hundred and ninety-one woody species, representing 204 invaders and 87 non-invaders were used to validate the decision tree. Invaders were identified based on herbarium collections and through contact with resource managers. Non-invaders were those listed in nursery and seed catalogues from early in the 20th century that had not escaped cultivation.

The Reichard and Hamilton decision tree was also tested on 57 woody species (serious pests and non-pests) of Hawaii by Daehler and Carino (2000). The model rejected 82% of invasive species and required further study for the remaining 18%. Most non-invaders were accepted (79%), while 10% were rejected and 10% required further study. However, the Australian Weed Risk Assessment (WRA) model (see below) was more accurate than this decision tree or the system developed for woody invaders in South African fynbos by Tucker and Richardson (1995) (Daehler and Carino, 2000).

Jefferson et al. (2004) tested a modified version of the Reichard and Hamilton model for use at the Chicago Botanic Garden, and compared it with the Australian WRA model (see below) and several modified Australian WRA models. The Reichard and Hamilton model resulted in a high proportion of species that required further evaluation, including 45% of what were known invasive species, and 55% of the known non-invasive species. The remaining invasive species (55%) were classified correctly as invasive. Of the non-invasive species, 30% were correctly classified as non-invasive and 15% were incorrectly classified as invasive.

Widrlechner et al. (2004) tested the Reichard and Hamilton model to predict the risk of naturalization of non-native woody plants in Iowa. Their application of the model to Iowa data resulted in an classification rate of only 65%. However, improvements to this classification rate were achieved by modifying the original, 'continental' model as well as by devising a new regional model. Their research demonstrated the value of incorporating locally important life history and geographic variables into broader 'continental' models.

In a study of woody species in the Czech Republic, Křivánek and Pyšek (2006) found the Reichard and Hamilton model inferior to the Australian WRA and the Hawaiian Weed Risk Assessment (H-WRA) (see below). On a dataset of 180 alien woody species, this model rejected only 35% of invasive species and accepted 65% of non-invasive species. It was the only model of the three to accept some invaders. The poor performance on this dataset may be related to the failure to take climatic factors into consideration as well as possible bias due to taxonomic classification, i.e. membership in a genus/family known to contain other invasive species (Křivánek and Pyšek, 2006).

Adaptability to different climates/ecosystems/growth habits: This decision tree was developed for woody invaders of North America. The authors indicate that the methods, but not the specific details, used to develop the decision tree could be useful for other taxonomic groups. They recommend caution in applying this decision tree to other taxonomic groups such as annual plants.

Křivánek and Pyšek (2006) suggest that with so few questions, the system is easy to use where developed, but limited in its applicability elsewhere.

Cost-effectiveness (ease of use, time required): The decision tree consists of seven questions. All or a portion of these questions require an answer in order to reach a conclusion. For the species tested, information needed for the evaluation was not difficult to find although the minimum juvenile period was identified as the most common unknown. Although the time required to complete an assessment was not indicated, judging by the number of questions, it is likely less than half a day. It is also straightforward and easy to use.

Scientific basis: Most of the plant characteristics evaluated for model development had been suggested in the literature. Traits were then selected based on their discriminatory power in discriminant analysis and decision tree models. The version of the decision tree that was selected had the lowest misclassification rate (Reichard and Hamilton 1997).

Objectivity: The questions in the decision tree are straightforward, and answers are either yes or no. So long as assessors adequately review relevant sources, results should be objective and repeatable.

Ability to deal with knowledge gaps: Inability to answer one of the critical questions in the decision tree would result in failure to reach a decision.

Australian Weed Risk Assessment System (WRA) (Pheloung et al., 1999)

The Australian WRA consists of 49 questions relating to the history, biogeography, biology, and ecology of weeds. Within these broader categories, questions fall under the following subheadings: domestication/cultivation, climate and distribution, weed elsewhere, undesirable traits, plant type, reproduction, dispersal mechanisms, and persistence attributes (Pheloung et al., 1999). Questions are answered based on information (literature, floras, databases) from parts of the world other than the country for which the assessment is being made. At least 10 questions, distributed in a specified manner across the categories, must be answered to complete the Australian WRA. In most tests of the Australian WRA, sufficient information has existed to allow response to more than 30 questions, on average (Gordon et al., 2008a).

The 49 questions are provided on a scoring sheet, and most are given an equal weight, though the point score associated with individual questions can range from -3 to 5 (Pheloung et al., 1999). Total scores range from -14 (benign) to 29 (maximum weediness). Score outcomes are as follows: <1 Accept, 1-6 Evaluate further, >6 Reject. For species that require further evaluation, more data can be gathered and the model re-run, or field research may be necessary. Partitioning of the total score between questions relating primarily to agriculture or the environment allows the assessor to determine whether impacts of the weed will be primarily agricultural or environmental. This designation may assist in regulatory decision-making.

Ability to discriminate between weeds and non-weeds: The Australian WRA rejected or accepted over 70% of 370 taxa, while 29% required further evaluation. The model was calibrated to reject all serious weeds while simultaneously rejecting a minimum of non-weeds (7%). Most minor weeds (84%) were rejected or evaluated (Pheloung et al., 1999). In subsequent tests, a secondary screen to reduce the number of species in the "evaluate further" category (Daehler et al., 2004) has consistently reduced that number to <10%. Major weeds are correctly identified at least 90% of the time, and non-weeds are correctly identified 70% of the time, when results from all geographies in which this system has been tested are averaged (Gordon et al., 2008b).

Testing and validation: The Australian WRA is well-known and has likely undergone the most testing and validation of any of the screening tools. The Australian WRA was formally adopted for regulatory use in Australia in 1997(Pheloung, 2005) and has been applied to over 2800 taxa. The original model was calibrated and tested by using 370 taxa representing serious weeds, minor weeds and non-weeds from a variety of sectors (agriculture, environment, horticulture, garden, service areas). Performance was assessed against expert opinion. Experts' classifications were significantly correlated with WRA score (r=0.686, P<0.01). The tool was found to be more decisive than two simpler methods, the AQIS/Hazard system (after Hazard, 1988) and that developed by Panetta (1993).

Since its inception, the Australian WRA and modified versions of this model have been tested in New Zealand (Pheloung et al., 1999), where it has also been implemented for regulatory purposes, Hawaii (Daehler et al., 2000), Illinois (Jefferson et al., 2004), the Galapagos Islands (Pheloung, 2005), Florida (Gordon et al., 2008a), the Bonin Islands (Kato et al., 2006), Italy (Crosti et al., 2007), Central Europe (Krivánek and Pyšek, 2006) and Japan (Nishida et al., 2008). Results from many of these tests are summarized and compared in Gordon et al. (2008b).

Daehler and Carino (2000) compared the accuracy of the Australian WRA with that of the Reichard and Hamilton (1997) decision tree and the Tucker and Richardson (1995) system, both designed for woody species only. In this Hawaii test, the authors determined the Australian WRA to be most accurate for all types of species (Daehler and Carino, 2000).

Jefferson et al. (2004) tested the Australian WRA for use on woody species at the Chicago Botanic Garden, and found that the model excluded all invasive species, but was poor at classifying non-invasives. Modifications to the model improved the classification of non-invasives drastically, reducing the number of false negatives from 55% to 15%. Approximately 40% of non-invasives were accepted and a further 45% required evaluation, based on the Chicago Botanic Garden-modified Australian model. Jefferson et al. (2004) also tested a shortened version of the Australian model, and with additional modifications, considered it to have potential for use at both regional and national levels. Although it had the advantage of a low rate of excluding non-invasives (5%), and was quicker to complete, it was not as accurate at identifying invasive species (65% correctly identified, 10% misclassified, and 25% evaluate further).

The Australian WRA was also effective at rejecting invasive woody species in a study by Křivánek and Pyšek (2006), but was outperformed by a Hawaiian modification of it (see the H-WRA below) in terms of correctly classifying non-invasive species.

A Review of the National Weed Risk Assessment System (Australian WRA) was conducted in 2006 by the Australian Primary Industries and National Resource Management Standing Committees, to consider concerns raised by stakeholders regarding its practical operation (NRMSC, 2006). The main concerns were the rejection of non-invasive plant material, which presents a problem for the horticulture industry, and potentially inconsistent results. The review indicated that the Australian WRA has demonstrated overall robustness and effectiveness. However, it could benefit from further refinement to retain its ability to reject invaders while increasing its acceptance of non-invaders. Suggestions provided in the review included raising the minimum number of questions that must be answered, excluding questions that are not easily answered or are insignificant, developing a second weed screening system for the 'further evaluate' category, providing an estimate of the probability of a species becoming a weed rather than a score, and others.

In Australia, 2800 plant species were proposed for introduction between 1997 and 2006. Using the Australian WRA, 53% of the species were accepted for import, 20% required further evaluation, and 27% of the species were rejected (Belinda Riddle, Biosecurity Australia, cited in Gordon et al., 2008b). A conservative analysis, described as underestimating the costs of damaging invaders and overestimating the benefits of species introduced, suggests that implementation of the Australian WRA in Australia resulted in reduced economic damage in just over ten years, with up to $1.8 billion in savings over 50 years (Keller et al., 2007). Similarly, a study by Caley et al. (2006) confirmed that the outcomes of the Australian WRA "appear consistent with a high expected cost of mistakenly introducing a weed."

Adaptability to different climates/ecosystems/growth habits: Although developed for plant invaders of Australia, the Australian WRA can be adapted for use in any region of the world, including temperate, subtropical and tropical regions. It can be used for plants of any growth habit (e.g. herbs, shrubs, trees). Furthermore, it provides an assessment of whether the taxon is likely to become invasive primarily in agricultural or environmental systems or both.

Cost-effectiveness (ease of use, time required): Answering the questions in the Australian WRA requires searching the international literature, floras and databases. Estimates of the time necessary to assess a single species range from 6 to 24 hours, on average (Gordon et al., 2008b). This time frame can be shortened if information required to answer the questions is provided by the importer or if the species is well known. The template and scoring system are straightforward to use, and additional guidelines for answering the questions are available to assist the assessor (Pheloung, 2005), with greater guidance currently under development (Gordon, pers. comm.) resulting from the Second International Workshop on Weed Risk Assessment, Perth, Australia in 2007. A copy of the Microsoft Excel spreadsheet version of the Australian WRA may be obtained from Plant Biosecurity Australia (http://www.daffa.gov.au/ba/reviews/weeds/system).

The length of time to complete the Australian WRA for a single species was considered prohibitively long for use at the Chicago Botanic Garden, where plant exploration trips can result in >100 taxa requiring evaluation (Jefferson et al., 2004). However, 1-2 days may be acceptable for federal regulatory agencies.

Scientific basis: The questions in the Australian WRA were selected based on accumulated knowledge from ecological and weed research, and are supported by empirical studies of invasive plants (Daehler et al., 2004). This non-experimental approach synthesizes conceptual models of plant invasiveness that are based on biology, bioclimatic information, and evolutionary history into a screening procedure (Pheloung, 1999). Weightings for the questions were determined manually to maximize discrimination between weeds and non-weeds (Caley and Kuhnert, 2006).

A criticism of this screening method is that it is not robust enough statistically to identify the most important characteristics or to assign appropriate weightings to the characteristics. Furthermore, it may be the case that not all questions are necessary. Additional research is required to determine which questions are most critical. Gordon et al. (2006), for example, tested a modified Australian WRA with a second screening (see the H-WRA, discussed below) for alien species in Florida, and found that they were unable to answer 12 of the 49 questions more than 33% of the time, and that these questions could be removed without a significant change in the result. While other systems have been derived from the Australian WRA, none have been as broadly tested.

Objectivity: The Australian WRA promotes objectivity by providing specific guidelines for answering questions and a list of references to survey. References used to answer each question should be documented for the purpose of transparency. Furthermore, the large number of questions reduces the weighting for any single question, which also serves to reduce assessor subjectivity (Biosecurity Australia, 2007). Results are less variable than those generated through expert opinion (Pheloung et al., 1999), although Cousens (in press) has observed that different users arrive at different scores. In general, this method promotes consistent results across different continents, geographies, hemispheres and species.

Ability to deal with knowledge gaps: Species may be assessed using the Australian WRA even when answers to some questions are lacking. However, reliability of the outcome and potentially, scores, increase with the number of questions answered. A minimum of 10, specifically distributed questions must be answered.
Although the system has been tested and slightly modified in other circumstances, the underlying model has never been seriously examined, and different model formulations (e.g., multiplicative) using the same information and scoring values have never been compared. Likewise, the thresholds set initially have never been re-tested or re-verified in the Australian system, although they have been corroborated somewhat by testing in other regions.

Hawaii Weed Risk Assessment System (H-WRA) (Daehler et al., 2004)

The Hawaii Weed Risk Assessment System (H-WRA) is a modified Australian WRA that uses an additional secondary screening to reduce the number of species that require further evaluation. Four of the 49 questions from the Australian WRA were modified to refer to the climate and soils of the Hawaiian and Pacific Islands rather than those of Australia. The secondary screening, which is applied only to species with scores between 1-6 (evaluate further), consists of two simple decision trees based on a subset of questions from the H-WRA. One decision tree is applied to tree or tree-like shrubs and the second is applied to herbs or low-stature shrubby life forms. The decision tree for trees and tree-like shrubs contains three criteria: 1) shade tolerant or known to form dense stands, 2) bird or clearly wind dispersed and 3) life cycle < 4 years. The decision tree for herbs and low stature shrubby life forms contains two criteria: 1) reported as a weed of cultivated lands and 2) unpalatable to grazers or known to form dense stands. Both decision trees are used for vines (Daehler et al., 2004).

Advantages and disadvantages of the H-WRA are similar to those of the Australian model. Differences, due to the addition of the secondary screening, are discussed below.

Ability to discriminate between weeds and non-weeds: For a set of almost 200 plant species introduced to Hawaii and the Pacific islands, the addition of the secondary screening improved performance of the WRA by reducing the percentage requiring further evaluation from 24% to 8% and increasing the number of non-pests admitted from 66% to 89%. The cost of these benefits was a rise in the number of minor pests admitted, from 16% to 33%. In both cases (with and without the second screening), 95% of major pests were rejected.

Overall, the H-WRA is very effective at identifying major pests and has a lower rate of indecision than the Australian WRA. As with the Australian WRA, it is more likely to reject non-invaders than admit invaders.

Testing and validation: The H-WRA was validated using nearly 200 plant species introduced to Hawaii and other Pacific Islands. Similar to validation of the Australian WRA, the H-WRA was validated by comparing its outcomes with that of expert opinions (botanists and weed scientists). Outcomes from the H-WRA and from expert surveys were positively correlated (r^2=0.52, P<0.001).

When compared with the Australian WRA and the Reichard and Hamilton (1997) models, the H-WRA performed the best on a set of 180 alien woody species in the Czech Republic (Křivánek and Pyšek, 2006). The H-WRA rejected 100% of invasive species and accepted 84% of non-invasive species. When overall accuracy was compared for the three models, the results were as follows: H-WRA (86%), Australian WRA (68%), Reichard and Hamilton (1997) (62%).

The H-WRA decreased the number of species requiring further evaluation without significantly reducing the accuracy of the prediction in both the Bonin Islands (Kato et al., 2006) and Florida (Gordon et al., 2008a) tests. Data for all tests are reviewed by Gordon et al. (2008b).

Adaptability to different climates/ecosystems/growth habits: Similar to the Australian WRA, the H-WRA would be readily adaptable to different regions of the world and address plants of all growth habits. Daehler and Denslow (2007) suggest that this model should be useful for application in Canada.

Cost-effectiveness (ease of use, time required): Cost-effectiveness of the H-WRA is comparable to the Australian WRA. The time required to complete the H-WRA would be insignificantly longer than the Australian WRA, because the answers to the secondary screening questions would likely have already been found while answering the first set of 49 questions. Daehler et al. (2004) state that most assessments were completed in 5-8 hours. Daehler and Denslow (2007) also indicate that a routine can be established for completing the risk assessment, using pre-defined sources to consult for each answer.

Scientific basis: In the secondary screening, two decision trees were developed rather than one because statistical trends indicate that agricultural weeds are more likely to be herbs whereas weeds of natural and semi-natural areas are more likely to be woody. The structure of the decision trees is based on logic, although the questions in the decision trees are based on factors empirically known to contribute to invasiveness (Daehler et al., 2004).

Objectivity and Ability to deal with knowledge gaps: In terms of objectivity and ability to deal with knowledge gaps, the H-WRA would be similar to the Australian WRA.

Caley and Kuhnert model (Caley and Kuhnert, 2006)

Caley and Kuhnert (2006) developed an optimal classification tree model with only four nodes, based on 44 attributes of introduced plants considered in the original Australian WRA model (Caley and Kuhnert, 2006). The four attributes retained in the decision tree model were 1) intentional human dispersal of propagules, 2) evidence of naturalization beyond native range, 3) evidence of being a weed elsewhere, and 4) a high level of domestication. Intentional dispersal of propagules by humans and ability to naturalize outside the native range were the strongest predictors of weediness for the taxa considered in the study. Intrinsic plant attributes were not selected by this model.

Ability to discriminate between weeds and non-weeds: In this study, major and minor weeds were pooled into a single category. Based on cross-validation of the decision tree, 93.6% of weeds were correctly identified as weeds whereas only 36.7% of non-weeds were correctly identified as non-weeds.

Testing and validation: The same dataset used to develop the Australian WRA system, consisting of 370 taxa (286 weeds and 84 non-weeds), was used to develop the decision tree. A 10-fold cross-validation approach was used to evaluate the ability of the decision tree to correctly classify new data. As well, its discriminatory performance, in terms of rejecting most weeds while simultaneously accepting most non-weeds, was characterized using a receiver operator characteristic (ROC) curve. Comparing the decision tree ROC curve with that of the original Australian WRA system, it was determined that the performance of the decision tree was slightly inferior.

Gordon et al. (2008a) found the full Australian WRA with the secondary screening introduced by Daehler et al. (2004) to be far superior for identifying invaders in Florida compared to the reduced Caley and Kuhnert (2006) model. When tested on a set of 151 species, the false positive rate was very high, at 90%. While this method was accurate for the major invader group, with all 61 species tested predicted to be invasive, it resulted in high predictions of invasiveness in the minor invaders (91% of the 47 species tested) and non-invaders (88% of the 43 species tested).

Adaptability to different climates/ecosystems/growth habits: Based on the nature of the four attributes that make up the decision tree, this model should be adaptable to any climate, ecosystem or growth habit.

Cost-effectiveness (ease of use, time required): Although the time to complete a single assessment was not specified by Caley and Kuhnert (2006), with only four questions, this decision tree is significantly simpler and quicker to use than either the Australian WRA or the H-WRA.

Scientific basis: The 49 questions used in the original Australian WRA were examined and reduced to 44 plant attributes by combining some questions (e.g., 3.02 *Garden/amenity/disturbance weed*, 3.03 *Weed of agriculture/horticulture/forestry*, and 3.04 *Environmental weed* became a single "weed elsewhere" question, and 7.06 *Propagules bird dispersed*, 7.07 *Propagules dispersed by other animals externally* and 7.08 *Propagules dispersed by other animals internally* became a new "Propagules dispersed by animals" question), and removing three questions that did not refer to intrinsic properties of the plant. From these 44 attributes, four questions were selected using software to develop a decision tree that optimized the classification of weeds and non-weeds.

Objectivity: The same guidelines developed for answering the questions of the Australian WRA could be used to answer the four questions of the Caley and Kuhnert (2006) decision tree, promoting objectivity.

Ability to deal with knowledge gaps: With only four nodes in the decision tree, missing information could result in the failure to classify a plant. However, answers to all four questions are not necessary. Based on the order of attributes in the decision tree, it is essential to know whether intentional propagule dispersal is likely or not. Beyond this, and depending on the outcome of the first node, either one or two additional questions must be answered.

Other Models

There are a number of other screening methods that have been developed in recent years. They are briefly described here, although not in detail since they are not likely candidates for use as a North American screening tool, for reasons such as limited adaptability to different growth forms or ecosystems, poor accuracy in identifying invasive and non-invasive species, or difference in intended use as compared to screening tools for intentional plant imports.

A decision tree model for screening woody alien plants for cultivation in South African fynbos was developed by Tucker and Richardson (1995). This model is not considered in greater detail here due to its specificity to woody species and invasion processes in fynbos as well as its poor performance in predicting invasive species when applied elsewhere and when compared to other models already discussed, i.e., Australian WRA (Daehler and Carino, 2000).

Frappier and Eckert (2003) developed a model to predict whether or not nonindigenous woody species would naturalize in New Hampshire. To develop the model, information on 42 plant characters, describing species physiology, morphology, reproduction and ecophysiological growth requirements, were gathered from the USDA PLANTS database and from other sources. The character "invasive elsewhere" was purposefully left out of the analysis. The resulting model retained 11 characters, and yielded an overall classification accuracy of 90% (91.4% of the naturalized species were correctly classified and 88.6% of the non-naturalized species). This study provides a useful approach for predicting naturalization success of introduced woody plants in New Hampshire, and highlights the importance of some ecophysiological characters in making these predictions. For the purposes of this discussion paper, the model has some important limitations that restrict its application over a broader scale. First of all, the model was developed for woody species only. Secondly, it predicts naturalization rather than invasiveness. Thirdly, the selection of some characters that were not considered important in other related studies would appear to indicate that the model may be constrained to localized geographic conditions. The authors suggest that similar studies could be performed at other locations, leading to a collection of predictive models based on local analyses that could be used for a screening policy, which is an interesting concept but likely rather difficult in practice. An additional limitation is the reliance on the USDA PLANTS database for many of the species' characters. This database contains species that are either native to or already introduced in the United States and would not contain the information required for most species proposed for introduction into North America.

Weber and Gut (2004) developed a model to assess the risk of potentially invasive plant species in central Europe. Their method was developed by modifying several existing protocols, including the Australian WRA, the Reichard and Hamilton model, and others. They included a useful pre-evaluation step to exclude species not justified for risk assessment, including widespread species, those already considered as quarantine species or under official control, and those unlikely to naturalize for obvious reasons. Those species that passed the pre-evaluation step were subject to a risk assessment scheme comprised of 12 questions on the species' biological characteristics, environmental preferences and distribution, and its history as a weed elsewhere. Similar to other assessments, there were three possible outcomes: low risk, intermediate risk (further observation required), and high risk. The overall accuracy of this system, which was tested on a combination of known invasive plants in Europe and exotic plants that have failed to establish, was 65%. The authors consider this system to be a first attempt at a risk assessment protocol for central Europe that requires further modifications.

Widrlechner et al. (2004) tested the Reichard and Hamilton model on non-native woody plants in Iowa, and also developed several modifications to the model that were successful in improving classification rates. The modified models included a *Modified decision tree*, a *Decision tree/matrix model*, and a *New CART* (classification and regression tree) *model.* These models differed from the original Reichard and Hamilton (1997) model in various ways, including the structure of the decision tree, the consideration of additional characters (production of fleshy, bird-dispersed fruits, evergreen foliage, geographic risk value), the use of a matrix to classify species requiring further analysis, and simplification of the decision tree using recursive partitioning of the data. The classification rates of the modified models ranged from 81% to 90%, compared to 65% for the original decision tree. These models require external validation and their development was restricted to woody species.

The Food and Agriculture Organization of the United Nations (FAO) produced a report called *Procedures for weed risk assessment* in 2005, based on a technical meeting held in Madrid, 2002, that was attended by weed specialists from several countries. The document presents a weed risk assessment system "for use by countries with limited access to information or resources to undertake weed risk assessments". The system incorporates international (IPPC) principles of weed risk assessment and a scoring procedure for risk factors that may be considered a simplified version of the Australian WRA.

Lastly, Parker et al. (2007) describe a model, the *U.S. weed-ranking model*, for ranking nonindigenous species according to their invasive potential in the United States. The purpose of this tool was to prioritize species for weed risk assessment so that they can be considered for listing as Federal Noxious Weeds. It is a scoring system that is based on other WRA systems (e.g. Australian WRA) and information on plant invasiveness from the literature. There are four elements to the model: entry potential, invasive potential, geographic potential, and damage potential. Together, a total of 33 factors are considered, and points are assigned based on the answer. A final ranking score, *R*, is the product of the four elements. The invasive potential element has the greatest effect on the final ranking. Results were similar to those of the H-WRA. This model is not considered in greater detail here due to its difference in intent, which is to rank species for consideration as federal noxious weeds in the United States, rather than to screen plants for import. Furthermore, there is an entry potential component that would produce the same result for all species intended for import.

Recommendations for NAPPO Guidelines

The guidelines should be a stand alone standard within NAPPO, but we foresee that similar guidelines eventually will be an annex to ISPM No. 11. The guidelines will provide guidance to NPPOs in determining the pest potential of a plant proposed for movement into an area where it is not yet present, and whether or not the plant should be regulated as a quarantine pest. The guidelines will address the screening of plants proposed for intentional import, not weeds unintentionally introduced in other commodities.

The purpose of the screening should be to reach a decision as to the admissibility of a particular plant based on its own potential pest risk. The outcomes would be to accept the plant, reject the plant, or evaluate the plant further. The outcomes of accept or evaluate further may lead to a separate evaluation of the plant for its potential to be a host for other plant pests.

The screening process should allow the NPPO to make a decision despite some unknowns, with the understanding that the accuracy of the outcome will improve with fewer unknowns. Areas of uncertainty should be documented.

The guidelines should allow the assessment to stop at certain cut-off points that determine if the subject plant fails to meet the definition of a quarantine pest. The NPPO should include the rationale for cut off points, if used.

The guidelines should acknowledge that invasiveness prediction tools range in complexity from the simplest (i.e., determining the accepted name, distribution, and evidence that the species is invasive elsewhere), to the complex (e.g., the Australian WRA method combined with a secondary screen and spatial modeling). The guidelines should not prescribe a particular method or format.

Because the screening process is to be used for first-time requests to import a particular taxon for planting, the NPPO can assume that the likelihood of introduction is high.

Overall, all three types of parameters should be considered together for a screening tool – biological, environmental (e.g., climate and spatial modeling) and history of invasiveness and associated impacts.

The parameters included in the screening tool may be selected based on expert opinion and/or a type of multivariate analysis (e.g. discriminant analysis, cluster analysis, principal components analysis, etc.).

The NAPPO guidelines for invasiveness screening should stipulate that the NPPO should test and calibrate screening tools with numerical cut off points, which would include testing the tool against plant species that are both known to be invasive and known to be non invasive in the country.

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