CHAPTER 13

ANALYSIS OF ENVIRONMENTAL RISKS

How to assess and manage risks of plants as pests?

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Abstract. Invasive alien plants can pose serious threats to cultivated and wild plants. This provides the basis to regulate them as 'plant pests' within the framework of plant health. To assess if a regulation would be appropriate, necessary and effective, and to identify available options for measures to reduce a possible risk, the revised International Standard on Phytosanitary Measures No. 11, "Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms" by the International Plant Protection Convention or the more operational decision support scheme for pest risk analysis by the European and Mediterranean Plant Protection Organisation, present useful tools. One of the challenges to assess the risks of alien plants to other plants and the environment is the identification of the plant's potential for invasiveness. In addition, the approach to the economic impact assessment is different in comparison to the 'traditional' plant pests. The level of uncertainty is often greater in the assessment of environmental risks than in risks to cultivated plants, and also management options in particular for intentionally introduced plants can differ significantly from those for traditional pests. This article focuses on risk analysis beyond traditional plant quarantine, and elucidates the features with regard to the assessment and management of invasive alien plants.
Keywords: International Plant Protection Convention; plant health; invasive alien species; phytosanitary measures; quarantine pests

INTRODUCTION

The consideration of a plant as a pest is at first sight a quite unfamiliar point of view. And certainly, most plants would not fall into this category. But some plants that have been introduced into new ranges have shown invasive behaviour and are posing serious threats to cultivated and wild plants. In the majority of cases, these threats are caused by indirect damage that affects plants primarily by processes such as competition for space and resources or change of habitats, e.g., by altering soil chemistry or water regime.

According to the International Plant Protection Convention (IPPC) and as confirmed by FAO (1998), organisms that are directly or indirectly injurious to any kind of plants can be regulated within the framework of plant health, which aims to

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prevent introduction and spread of organisms harmful to plants and to promote appropriate measures for their control. Habitats and ecosystems can be protected from the consequences the introduction of an invasive alien plant may have, as they are essential for the survival of plants. Plant health is implemented in Europe by a long established and well developed system. Traditionally, only direct pests of plants (viruses, fungi, insects etc.) are regulated by this system, but the regulation of indirect pests – in particular invasive alien plants – is now under discussion.

The plant health system bases its phytosanitary measures on pest risk analysis (PRA), in order to assess whether an organism has a negative impact on plants and whether it should be regulated. The risk of introduction and spread of this pest is assessed and – if appropriate – options for measures are evaluated and proposed. Standards by the IPPC, in particular the International Standard on Phytosanitary Measures (ISPM) No. 11 “Pest risk analysis (PRA) for quarantine pests”, and by the European and Mediterranean Plant Protection Organisation (EPPO) are available to facilitate this procedure. The EPPO standards, “Pest Risk Assessment Scheme” (Standard PM 5/3(1), EPPO 1997) and “Pest Risk Management Scheme” (Standard PM 5/4(1), EPPO 2000) were designed as user-friendly schemes to facilitate the conduct of PRA. Since they are based on the IPPC Standards, PRAs done with these schemes also provide – like PRAs based on the IPPC-PRA Standard itself – technical justification for the regulation of these organisms by states in the EPPO region. This is in accordance with the Sanitary and Phytosanitary Agreement under the World Trade Organisation (WTO 1994). Both IPPC and EPPO standards have recently been adapted to be better applicable to alien plants (for a background, see Schrader and Unger (2003)), because there are some significant differences in comparison to the ‘traditional’ plant pests. The revised ISPM No. 11 “Pest Risk Analysis for Quarantine Pests, Including Analysis of Environmental Risks and Living Modified Organisms” dating from 2003 is publicly available at the IPPC homepage (www.ippc.int). The two EPPO Standards for Pest Risk Assessment and Pest Risk Management have been combined to a single Standard on Pest Risk Analysis. This standard is fully in line with the revised IPPC Standard and will be available at the EPPO homepage (www.eppo.org) by the end of 2005. For the import of plants that are invasive or potentially invasive, another EPPO standard has been drafted addressing specific measures for such situations. This draft standard is currently under country consultation by the EPPO member states.

The objective of this paper is to describe an approach to evaluate the probability of the introduction and spread of invasive alien plants and the magnitude of the associated potential economic, including environmental, consequences. Differences between PRA for traditional pests and plants as pests are highlighted, and it is shown that management measures especially for intentionally introduced plants can differ significantly from those for direct pests of plants.

PLANTS AS PESTS

From a traditional plant pest, like a pathogen, a phytophagous insect or nematode, it is usually known beforehand that it can be harmful to plants, at least under certain conditions. For alien plants, the potential to cause damage is more the exception than the rule, and is often much more difficult to evaluate and to quantify. But in plant quarantine, an organism can only be regulated if it fulfils the criteria of a pest of plants and is of potential economic importance to the area endangered thereby (IPPC 1999). This includes by definition the consideration of environmental importance. A specific standard supplement (Glossary of Phytosanitary Terms, ISPM No. 5, Supplement No. 2, Guidelines on the Understanding of Potential Economic Importance and Related Terms Including Reference to Environmental Considerations from 2003) gives some details on this inclusion of environmental importance.

According to the Guiding Principles for the Prevention, Introduction and Mitigation of Impacts of Alien Species (CBD 2002) of the Convention on Biological Diversity (UNEP 1992), invasive alien species are non-indigenous organisms that threaten biodiversity. Consequently, an organism that solely poses a risk to crops or otherwise cultivated plants does not fall into the scope of the CBD. But an organism that does not have any adverse effect on crops or cultivated plants, can be considered a quarantine pest (definition: IPPC 1999), as long as there is a direct or indirect effect on other plants (ICPM 2001). An organism threatening biodiversity via an impact on plants fulfils the definitions for both an invasive alien species and a quarantine pest. Accordingly, all relevant threats to biodiversity as a consequence of the introduction and spread of organisms directly or indirectly harmful to plants are covered by the IPPC.

RISK ASSESSMENT OF ALIEN PLANTS

The first PRA standard by the IPPC, ISPM No. 2 “Guidelines for Pest Risk Analysis” from 1996 is currently under revision, describing the basic concept of pest risk analysis within the framework of the IPPC. It introduces the three stages of pest risk analysis – initiation, risk assessment and risk management – and the components for collecting, recording and communication of information. The initiation stage is explained in detail in this standard. Reference to other ISPMs, e.g. ISPM No. 11, is made regarding the risk assessment and risk management stages. The initiation stage aims at the recognition of organisms and pathways of phytosanitary concern that should be considered for pest risk assessment in relation to the identified PRA area. By risk assessment, the probability of the introduction and spread of a pest and the magnitude of the associated potential economic consequences are evaluated. With regard to alien plants, main questions are: does the plant have a high potential for spread and does it damage or threaten biodiversity? How is damage to be defined? Which effects does it have on other plants, on habitats, on ecosystems? In this context, it is important to define or estimate thresholds for invasiveness and environmental risks. Comparisons with other species, similar situations or experience from previous PRAs may help to answer these questions. Answers should be as objective and comprehensible as possible.

Introductions of alien plants into a country are intentional or unintentional and can be subjected to different motivations. For intentional introductions, the motivation is in most cases the trade with the plant itself, usually there is an interest on both sides, the exporter and the importer, to introduce this plant into a country. For unintentional introductions, the motivation is the trade with another subject, but this subject may be contaminated by plant propagules. Accordingly, some details for risk assessment differ for these two different situations.

Intentional introductions

In traditional PRA, it has to be assessed whether and how a pest can enter a country. For alien plants for planting, this is not necessary, as the entry is intended – such plants are intentionally imported, traded and planted. Instead, it is important to look at the pathway from the intended to the unintended habitat and the probability of establishment in the unintended habitat – in other words: can the plant escape from where it has been sown or planted? This assessment involves for example the consideration of climatic and other abiotic factors, the reproductive strategy of the plant species, the possibility of prevention of establishment by natural enemies or by competition from species present in the PRA area, and the likelihood of mitigation of impacts (eradication, containment or control) of the species after introduction.

Even the escape from an intended habitat is not causing any harm in probably most cases. A lot of plants are not able to establish permanently, others just blend into the environment without causing any problems. The tens rule (Williamson 1996), stating that 10 % of introduced species spread, 10 % of these establish, and 10 % of the established species cause problems (= 0.1 %), is tolerably applicable to alien plants. The difficulty is to identify this (approximately) 0.1 % that could be harmful among the plant species being introduced into a country or a region.

Examples for plants that have been introduced intentionally and that are causing problems now in Germany are Japanese knotweed (*Fallopia japonica*), American skunk-cabbage (*Lysichiton americanus*), giant hogweed (*Heracleum mantegazzianum*), golden rod (*Solidago canadensis* and *S. gigantea*) and black locust (*Robinia pseudoacacia*).

Unintentional introductions

Invasive alien plants may also be introduced unintentionally into a country as, e.g., contaminants of seeds, bird seed, oil seed, grain, fodder, wool, with soil or other growing medium, attached to vehicles or machines or in containers used for shipping. An example is annual ragweed (*Ambrosia artemisiifolia*), which is native to North America. This plant is introduced, e. g., with contaminated sunflower bird seed. Chufa flatsedge (*Cyperus esculentus*) has been unintentionally introduced and spread by vehicles and contaminated seed.

To reduce the risks of unintentional introductions of invasive alien plants, it is important to consider relevant pathways and to estimate the probability of the pest plant being associated with the pathway at origin. For example, in the case of *A. artemisiifolia*, it would be important to know if a sunflower field from which bird seed is produced is contaminated with plants of *A. artemisiifolia*, and if these plants are able to produce viable seeds. Also, it has to be considered if measures are applied to reduce or avoid contamination.

Also for unintentional introductions, the likelihood of spread and the potential to cause damage have to be assessed.

Assessment of the plant's potential for invasiveness

One of the challenges to assess the risks of alien plants is the identification of the plant's potential for invasiveness – this will probably in most cases be the major difficulty in the whole PRA. A key issue within PRA is to find out if the assessed organism has intrinsic attributes indicating that it could cause significant harm to plants or plant communities. Attributes of plants which could be relevant for invasiveness are broad ecological amplitude and high adaptability, ability to produce many seeds or vegetative propagules and to build up a persistent seed bank, and high competitive strength; see, for example, Rejmánek and Richardson (1996), Rejmánek (2000) and Heger and Trepl (2003). Important questions are also if the species is invasive in its area of current distribution, if the chances for rapid natural spread are high, if the propagules are highly mobile or if the plant benefits from cultivation or browsing pressure, and if there is a likelihood of building up monospecific stands. These attributes may increase the likelihood of invasion, but they are not in any case necessary for invasion success. On the other hand, a plant may have all these attributes without causing any problems. A big obstacle to general predictions is that there are no known broad scientific criteria for all (potentially) invasive plants in all relevant circumstances. Several publications deal with difficulties related to prediction of invasiveness (e.g. Williamson and Brown 1986; Kolar and Lodge 2001; Williamson 2001; Heger and Trepl 2003). According to Williamson (1999) invasiveness elsewhere is a comparably consistent predictor.

To get a better prediction of the plant's ability to invade, experimental plantings could be an option, but the time-lag effect is difficult to be assessed. An invasion is often triggered by planting large volumes of a plant species, and by repeated and secondary introductions (see e.g. Kowarik 2003) – therefore, intended use and volume of the introduction of a plant species need to be taken into account as well. The success of a plant in invading a certain area will also depend on the susceptibility to invasion of the related habitat, so this has to be considered too (Heger and Trepl 2003). Often, sites modified by man or strongly disturbed grounds are especially prone to invasion. With regard to the alien plant's requirements, nutrient-rich or nutrient-poor soils (or waters) may be preferred, and some plants, like *Lysichiton americanus*, are predominantly found in vegetation close to nature (Alberternst and Nawrath 2002).

Despite all these difficulties, a screening for first-time introductions of plant species would be useful, with simple criteria, especially invasiveness elsewhere, followed by an in-depth risk analysis in case there is some indication for invasiveness.

Primary and secondary consequences resulting from establishment and spread

If a species has been identified to be invasive or potentially invasive, the next step is to specify the concrete possible consequences of establishment and spread. In this context, primary and secondary consequences have to be considered. Regarding environmental risks, important primary consequences would be for example the reduction of the abundance of keystone plant species, which are 'responsible' for the existence of an ecosystem of a certain type, or are the main drivers for the development of or succession within an ecosystem. Also, for species that are major components of ecosystems, the decision may be taken that they should be protected, because reduction of their abundance will certainly change the habitat or ecosystem that is dependent on them and this change is not desired. This would especially be the case if their reduction causes the ecosystem to degrade or to collapse. Negative impacts on endangered native plant species must also be prevented in order to protect biodiversity. Furthermore, protection of other plant species against significant reduction, displacement or elimination is taken into account, though endangered species receive more attention than just 'normal' species because of their status.

Examples for secondary consequences relate to significant effects on plant communities, significant effects on designated environmentally sensitive or protected areas, significant changes in ecological processes and of the structure, stability or dynamics of an ecosystem (including further effects on plant species, erosion, water-table changes, increased fire hazard, nutrient cycling, etc.), effects on human use (e.g., water quality, recreational uses, tourism, animal grazing, hunting, fishing), or costs of environmental restoration. If for example the symbiotic nitrogen-fixing black locust (*Robinia pseudoacacia*) is invading certain habitats it may have a significant effect on the whole plant community, because ecological processes may be affected by an accumulation of nutrients due to nitrogen enrichment of the soil. This has a significant negative impact on nutrient-poor soils, which often are habitats for endangered plant species. In invaded regions in Poland, enrichment of soil nitrogen by *R. pseudoacacia* is thought to favour the appearance of certain combinations of associated species (Dzwonko and Loster 1997).

Yet another example is the damage that could be caused by the aquatic plant New Zealand pygmyweed (*Crassula helmsii*). Its vegetative growth leads to dense mats that can block ponds and drainage ditches, and even outcompete native flora and impoverish the ecosystem for invertebrates and fish. The vegetation mats can be dangerous to pets, livestock and children who confound them with dry land. *Hydrocotyle ranunculoides*, another aquatic plant, may change aquatic habitats by excluding light from the water, reducing photosynthesis to a significant extent.

Other negative impacts of introduced invasive alien plants can be allelopathic effects or hybridization. *Ailanthus altissima*, for example, has allelopathic effects on many other tree species and may consequently inhibit succession (Heisey 1996). Alien species can hybridize with closely related natives, which may lead to a loss of genetic and species diversity. An example is the American grass species *Spartina alternifolia*, which was accidentally introduced and hybridized with *S. maritima* in Britain, producing *S. x townsendii*. The hybrid led to a tetraploid species, *S. anglica*, which outcompeted the parent species and is invading successfully British wetlands (Gray et al. 1991; Thompson 1991). Alien plant species may also hybridize with other non-natives, possibly leading to the evolution of a stronger, more vigorous hybrid. This has been observed with the hybridization of *R. japonica* and *R. sachalinensis*. resulting in the highly invasive hybrid *Reynoutria x bohemica* (Pyšek et al. 2003).

Assessment of economic consequences

Estimations of consequences of introduction, establishment and spread of an alien plant made up to this point, related to the hypothetical situation that it has been introduced and fully expresses its economic consequences in the PRA area. But in practice, economic consequences are related to time and place factors. The total economic consequences for more than a year can be expressed as net present value of annual economic consequences, and an appropriate discount rate selected to calculate net present value. Economic consequences also depend on speed of spread, on the number of habitats infested and a change of relevant factors over time.

Environmental effects can be of an economic nature, without having an existing market that can be easily identified. Therefore, the effects may not be adequately measured in terms of prices in established product or service markets. These impacts could be approximated with an appropriate non-market valuation method. The assessment of consequences may be quantitative or qualitative. Often, qualitative data are sufficient. A quantitative method may not exist to address a situation (e.g., catastrophic effects on a keystone species), or a quantitative analysis may not be possible (no methods available).

For a valuation of the environment, ISPM No. 11 provides different methodologies, including the consideration of 'use' and 'non-use' values. 'Use' values can be separated into consumptive (e.g., fishing in a lake) and non-consumptive (e.g., using forests for leisure activities). 'Non-use' values can be divided into option value (value for use at a later date), existence value (knowledge that an element of the environment exists), and bequest value (knowledge that an element of the environment is available for future generations). To assess these values, methods are available referring to market-based approaches, surrogate markets, simulated markets, and benefit transfer. Also, the assessment can be based on non-monetary valuations, such as number of species affected or water quality. In any case, these methodologies are best applied in consultation with experts in economics. The procedures should be documented, consistent and transparent and environmental values should be clearly categorized.

Uncertainty

The level of uncertainty is often greater in the assessment of risks to the environment than of risks to cultivated plants, due to the lack of information, additional complexity associated with ecosystems, and variability associated with pests, hosts or habitats. Generally, phytosanitary measures are intended to account for uncertainty but should not be more stringent than necessary. For the identification of management options it is important to consider the degree of uncertainty.

RISK MANAGEMENT OF ALIEN PLANTS

If the assessment of an organism for which the PRA is being done reveals an unacceptable risk to plants in the PRA area, management options have to be identified to reduce or exclude these risks. The situation with unintentionally introduced invasive alien plants (as, for example, propagules or hitchhikers with other plants) is comparable with other plant pests – measures may be determined that block or reduce entry and spread via the identified pathway(s). But with intentionally introduced plants, management options are quite different. The management part of ISPM No. 11 does not give detailed guidance on how to proceed with the import of invasive or potentially invasive plants. In the framework of EPPO, a standard for the import of alien plants has therefore been drafted that will most certainly be adopted by the EPPO Council in autumn 2006. Important points to consider are: the surveillance after planting, the preparation of control or emergency plans if a plant is found outside its intended habitat and spreads to an unacceptable degree, the restriction on import, sale, holding and on planting (including authorization of intended habitats, prohibition of planting in unintended habitats, required growing conditions for plants), the notification before import, restrictions on movement (e.g., prevention of movement to specified areas), and the obligation to report findings. In any case, the intended use of the plant is influencing the choice of management measures. A differentiation between the intended use of species, e.g., for gardening (within urban areas) or for landscaping (planted in large numbers, at many different locations, in the countryside) can also influence the selection of possible measures. The decision if such measures have to be applied to certain imported plants needs to be based on a pest risk assessment. A quick screening of the plant should indicate whether a detailed risk assessment is necessary. If this is the case, and an unacceptable risk is identified, the most appropriate measures as indicated in the draft EPPO standard could be selected.

For plants new to a territory, it is difficult to predict their ability to invade. If an invasive behaviour has never been observed before but some characteristics or attributes of the plants and their potential habitats raise suspicion for invasiveness, an option could be not to take phytosanitary measures at import, but to apply surveillance or other procedures after entry and to monitor plants after import and planting. The decision to select the most adequate approach has to be based on expert judgement – usually, this would be the risk assessor. This could be combined with an emergency plan to be used when the plant is found outside its intended habitats in undesirable numbers. Also, the phenomenon of 'time lag' has to be considered – some invasive species, especially plants, only show invasive behaviour after a considerable time.

As measures for ornamental plants may be difficult to understand for the public, raising of publicity is an important point in this context. Measures may easier be accepted for clear-cut cases than for plants for which only a risk potential has been identified.

REGULATORY FRAMEWORK FOR INVASIVE ALIEN SPECIES AFFECTING PLANTS

The international regulatory framework for organisms that are directly or indirectly injurious to any kind of plants is provided by the International Plant Protection Convention (IPPC), which is an international treaty adopted in 1952 and revised in 1979 and 1997 (IPPC 1999). Its aim is to secure action to prevent the spread and introduction of pests of plants and plant products, and to promote appropriate measures for their control. Promoted by an increased awareness for the protection of the environment, the IPPC has started in 1999 to identify explicitly how its implementation directly relates to the identification of environmental risks caused by plant pests. Although the IPPC addresses the spread of pests associated with international trade, the Convention is not limited in this respect – it is focussed on the protection of plants in general. This includes the protection of biodiversity, and many provisions, procedures and standards of the IPPC are directly relevant to, or overlap with, the aim of article 8 (h) of the Convention on Biological Diversity (CBD), which requires contracting parties to "prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species" (UNEP 1992). In order to clarify the role and competence of the IPPC, to avoid overlaps and double work, and to achieve a synergistic approach regarding the protection against invasive alien species with impacts on plants, the IPPC works collaboratively with the CBD. A memorandum of cooperation between IPPC and CBD has been adopted in 2004.

Regional Plant Protection Organizations provide coordination on a regional level for the activities and objectives of the IPPC and help contracting parties meet the Convention's obligations. The Regional Plant Protection Organization for Europe, Russia and several other countries from the former Sowjet Union, as well as some countries of the Middle East and North Africa, is the European and Mediterranean Plant Protection Organisation (EPPO). It was founded in 1951 with its own convention. Following to the activities of the CBD and the IPPC (see, e.g., Schrader and Unger 2003), the European and Mediterranean Plant Protection Organisation is developing a new working program on invasive alien species and 'pest plants'. EPPO gives recommendations to its 47 member countries on how to assess and manage invasive alien plants. Plants are listed on the new EPPO list for invasive alien plants (consisting of 34 species at the moment; http://www.eppo.org/QUARANTINE/ias_plants.htm) or on the EPPO action list (2 species at the moment: *Hydrocotyle ranunculoides* and *Lysichiton americanus*; http://www.eppo.org/QUARANTINE/action_list.htm).

Phytosanitary measures in the European Union have been fully harmonized in 1993, when the EU internal market was established. With EU Council Directive 2000/29/EC (European Commission 2000) protective measures against the introduction of organisms harmful to plants or plant products into the EU Member

States from other EU Member States or from third countries are regulated. Similarly, protective measures against the spread of harmful organisms within the Community through movements of plants, plant products and other related objects within a Member State are included.

One of the most important measures in this Directive is the listing of harmful organisms whose introduction into the community must be prohibited. The related annexes to the Directive list quarantine pests as well as plants, plant products and other articles that could be pathways for these quarantine pests. Their introduction and movement into or within the EU are prohibited or subject to certain requirements or restrictions. These annexes contain binding measures for more than 200 organisms. Currently, mainly pests directly harmful to cultivated plants, like insects, nematodes and viruses, are listed. Many of these organisms also pose a threat to biodiversity. Invasive alien plants have not been enclosed in these annexes up to now – besides some non-European parasitic plants of the genus of *Arceuthobium* – but their inclusion is presently under discussion. First candidates are *Hydrocotyle ranunculoides* and *Lysichiton americanus*, which are already listed at the EPPO Action list.

In addition to these ‘black lists’, implementing provisions may be adopted to lay down conditions for the introduction into the Member States and the spread within the Member States of organisms that are suspected of being harmful to plants or plant products but are not listed.

CONCLUSIONS

In this paper it has been shown that different aspects are relevant for the assessment and management of invasive alien plants in comparison to traditional pests of plants. As plants are usually not pests or do not behave like pests in their area of origin, it is often difficult to predict their potential risks to other plants if introduced to new areas. Management measures have to be selected in proportion to the risk – the higher the risk, the more stringent a measure.

For invasive alien plants that threaten other plants or plant products and for the analysis of environmental risks, the revised IPPC and EPPO standards on PRA provide the necessary elements for a substantial risk analysis. As these tools have originally been used for traditional pests and have only recently been revised to be better applicable to the assessment and management of environmental risks, experience for their application and the implementation of their results in this regard has yet to be increased. However, contracting parties (number as of 14 October 2005: 141) to the IPPC benefit from having in place long-established IPPC-based systems for the prevention of introduction and spread of plant pests and can abstract experience from this source to environmental risks. Especially the assessment of risks posed by alien plants to a PRA area is a difficult task because of high levels of complexity in ecosystems, uncertainty about threats to biodiversity, pressure arising from globalization including trade and tourism, etc.

Results of the PRAs can be used for recommendations by EPPO to its Member Countries, including proposals for management options. PRAs and EPPO management options could provide the basis for the EU Commission and accordingly for separate EPPO Member Countries that are not EU Member States to regulate specified invasive alien plants, including prohibition of import or conditions for introduction or use.

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