SESSION 2

TRADE AS A PATHWAY FOR THE INTRODUCTION AND SPREAD OF ALIEN SPECIES

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Ornamental horticultural trade as pathway for invasions

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ABSTRACT

A total of 403 ornamental species known to have started an invasion process in the UK were compared with a sample of 394 ornamental species not occurring outside cultivation. The results showed that the percentage of species on sale in the last century, and the frequency with which they have occurred in the marketplace, has always been higher in the invading sample than in the non-invading sample. Furthermore, the invading species more often than the non-invading species, originate in Europe and Asia, and belong to a genus native in Britain.

INTRODUCTION

Deliberate introductions of plant species are recognised to be the main source of non-indigenous species in many countries (Groves 1998; Reichard & White 2001; Mack 2003). Horticulture promotes invasions in many different ways, of which the introduction of plants is the most obvious. For instance, gardening fashions lead to the rapid distribution of species across a country. Plant characteristics that make a plant interesting for gardeners, such as climatic suitability or quick propagation, may also promote a successful invasion. As a result, the rate of naturalisation is higher in deliberately introduced plants as compared with accidental introductions (Kowarik 2003).

In this paper, we are interested in understanding the extent to which horticultural trade may contribute to the invasion of non-native species in natural ecosystems. Studies of the trade in pet animals such as parrots (Cassey *et al.*, 2004) and aquarium fish (Semmens *et al.*, 2004; Duggan *et al.*, in press) have shown a relationship of the availability and frequency of species in the international and national trade with its invasion success. In the middle of the 19th century, in south-eastern Australia, Mulvaney (2001) analysed nursery catalogue records to explore the links between availability of woody plants and their invasion. In this study we extend this work by focusing on the horticultural trade in Britain over the past 120 years, and we compare samples of ornamental non-native species which have and have not become invasive. Studies comparing invasive species with non-invasive species have been shown to be a good method to describe traits of invasive species (e.g. Frappier & Eckert, 2003). Here, we use it to include socio-economic factors as well as plant characteristics in the analysis.

DATA COLLECTION AND ANALYSIS

For the purposes of this analysis, we compare two groups of non-native ornamental plant species: invading and non-invading species. The invading group includes all species listed in the catalogue of alien plants of the British Isles (Clement & Foster, 1994; Ryves *et al.*, 1996) as garden escapes and as having at least 15 localities in the area. This group comprised 403 established and casual species (following the nomenclature in Richardson *et al.*, 2000). For the non-invading group, a sample of 600 non-invading species was randomly drawn from eight nursery catalogues printed in the middle of the 19th century (between 1854 and 1869). We chose eight nurseries known to be among the leading companies at that time (Hadfield, 1960) that were located in different parts of Britain. Native species, species found outside cultivation anywhere in the British Isles (and species twice in the list owing to synonymy) were excluded, resulting in a final data set of 394 non-invading species.

Information on the availability of these samples of non-native plants in the horticultural market were collected, using nursery and seed catalogues over the past 120 years. Thus, starting from 1885, the occurrence of these 797 species in five nursery catalogues was checked every 20 years. The Plant Finder 2004 (Royal Horticultural Society, 2004) provides the opportunity to compare our results from the nursery catalogues with a data source that included the whole range of ornamental species available in the market today. Further variables included in the dataset were the plant family, whether or not a species belongs to a genus native in Britain, and the native range. These data were mostly taken from Brickell (1996), Klotz *et al.* (2002) and Preston *et al.* (2002).

Frequency analysis was used to examine whether the two groups have statistically significant differences in the attributes examined in this paper. Dichotomous variables were coded as 1 (present or yes) and 0 (absent or no). For the analysis of the native range of the various species, each species was dummy coded into separate dichotomous variables for the following regions: Africa, America, Asia, Australia and Europe. Species originating in cultivation were included in an additional category. The total number of scores is higher than the number of species included in the analysis because many species are considered native to more than one continent. The frequency in the market for each ornamental non-native plant is defined as the number of nursery and seed catalogues in which that plant was present at each time period. We assume that the higher the frequency the more accessible is the plant and the more likely it is that the species has been bought and planted. To analyse the relationship between invading and non-invading species with their frequency in the market in the whole period studied, the species were grouped into 6 categories of 75, based on their frequency order. Category 7 contains the remaining 113 species (all with the same frequency). Species order was randomised within frequencies, in those cases where there was overlapping

RESULTS

Native range of the species

Compared with the non-invading sample, invading species were more frequently native in Europe, Asia and Africa or originated in cultivation. Species of American origin were the biggest group (33%) in the non-invading group. They contributed only half this percentage to the invading sample. Species originating in cultivation (hybrids) occurred more frequently in the invading sample. The difference between the two samples was highly significant (Chi-sq = 49.00, d.f. = 5, $P < 0.001$).

Taxonomic description

The sample included species from 122 plant families with 21 families contributing more than 10 species. The frequency with which species of both samples occurred in these families were significantly different (Chi-sq = 100.52, d.f. = 20, $P < 0.001$). Invading species were particularly dominant in the families Asteracea, Liliaceae and Rosaceae and the non-invading species in the families Fabaceae and Ranunculaceae (Table 1).

Table 1. Number of species of the non-invading and invading sample in the 21 plant families contributing more than 10 species to the total sample.

Family	Non-invading	Invading	Family	Non-invading	Invading
Asteraceae	24	55	Saxifragaceae	12	5
Fabaceae	55	13	Campanulaceae	7	8
Rosaceae	9	45	Onagraceae	7	8
Scrophulariaceae	14	21	Boraginaceae	3	10
Liliaceae	10	24	Ericaceae	7	6
Ranunculaceae	22	7	Crassulaceae	7	5
Lamiaceae	10	16	Caprifoliaceae	3	9
Brassicaceae	8	13	Malvaceae	5	7
Caryophyllaceae	13	8	Poaceae	10	2
Iridaceae	9	11	Solanaceae	6	5
Primulaceae	13	4			

Four hundred of the species belonged to a genus native in Britain, with 235 species of the invading and 165 of the non-invading sample. The difference between the two groups was highly significant (Chi-Sq = 20.87, d.f. = 1, $P < 0.001$).

Availability in the horticultural market

To test if the availability in the market is related to the ability of the species to become an invader, we compared the proportion of species found in nurseries catalogues in each group. The data showed that the percentage of species which had been available in the market in the different periods studied was always higher in the invading groups than in the non-invading species. The difference in the proportion of species on sale between the groups was small for the first period studied, but this difference increased with time during the first half of the period studied and stabilised in the second half. Highly significant statistical differences were found in the frequencies of species on sale in the periods studied, with the exception of the year 1885 (in 1885: Chi-sq = 1.88, d.f. =1, $P > 0.1$; in 1905: Chi-sq = 58.94, $P < 0.001$; in 1925: Chi-sq = 83.12, $P < 0.001$; in 1945: Chi-sq = 145.95, $P < 0.001$; in 1965: Chi-sq = 143.10, $P < 0.001$; in 1985: Chi-sq = 148.20, $P < 0.001$; in 2005: Chi-sq = 174.41, $P < 0.001$). Similarly, the proportion of invading species on sale according to the Plant Finder 2004 was higher than that of non-invading species. The difference between the two groups was highly significant (Chi-sq = 166.52, d.f. = 1, $P < 0.001$).

Occurrence frequency in the horticultural market

In order to explore the relationship between the frequency in the market and the invasion success, we first compared the proportion of species in the two groups that appeared at least in two of the five catalogues examined every 20 years. We focussed, thus, on the species most frequently on sale, given that the average of the third quartiles for the series examined was two nurseries. For all the periods, the invading species group contained a higher percentage of species that were on sale in at least two nurseries. On average, this percentage was 29% for the invading group and 7% for the non-invading sample. The χ^2 test shows that these groups were significantly different statistically in their popularity in the horticultural market in all years examined (in 1885: Chi-sq = 5.40, d.f. =1, $P < 0.05$; in 1905: Chi-sq = 36.35, $P < 0.001$; in 1925: Chi-sq = 70.35, $P < 0.001$; in 1945: Chi-sq = 87.37, $P < 0.001$; in 1965: Chi-sq = 89.14, $P < 0.001$; in 1985: Chi-sq = 60.54 $P < 0.001$; in 2005: Chi-sq = 106.58, $P < 0.001$). We also examined the frequency of the non-native ornamental species in the nursery catalogues for the whole period. In this analysis only those plants that appeared at least in one catalogue were included. This reduced our sample size to 219 in the non-invading group, and to 344 in the invading group. Only a small percentage of the non-invading species were among the most commonly frequent ornamental plants in the total sample (rank 1) (Figure 1). This percentage increases as we move along the ranks towards those with the least frequent species. The percentage of the species from the invading group in the different ranks seemed to be less variable, although it is declining towards ranks presenting species less frequently on sale.

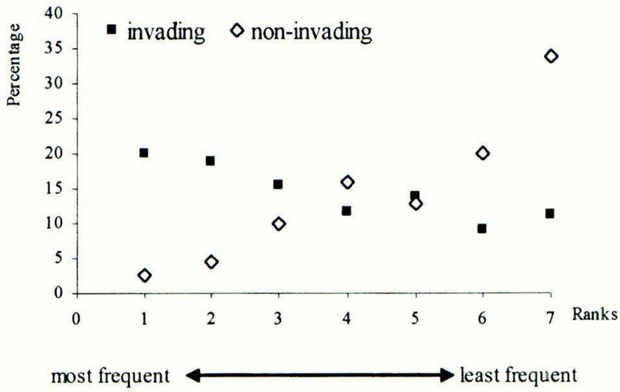

Figure 1. Percentage of invading and non-invading ornamental plants available in the horticultural market at least in one of the following periods: 1885, 1905, 1925, 1945, 1965, 1985, and 2005. Invading plants were ranked according to the frequency which they occurred in the nursery catalogues in these periods.

DISCUSSION

Our comparisons of invading and non-invading ornamental species show significant differences in their ecological as well as trade-related characteristics. The analysis of the areas of origin is in line with descriptions of alien floras in Europe, where species of

European and Eurasian origin have been shown to be the most frequent invaders (Pyšek *et al.*, 2002; Kühn & Klotz, 2003). The high percentage of American species in the non-invading sample compared with the low percentage in the invading sample suggests that species of American origin might be less likely to start an invasion process. This may, however, also be caused by the lower resident times of these species. The taxonomic description of the species shows that plant families such as the Asteraceae or Brassicaceae, which are over-represented in alien floras worldwide (Pyšek 1998), are also more frequently represented in our invading species sample. Pyšek (1998) also found families contributing to the alien species pool which were supported by deliberate introductions (for example the Liliaceae or Rosaceae) that are also over-represented in the invading species group of our analysis. In contrast to Pyšek's results, however, we found the Fabaceae under-represented.

The results show a clear relationship between availability and frequency in the market of non-native plants in the last 120 years and the current status of the plants as invading or non-invading. In the invading group there is a higher percentage of species that have been on sale (i.e. available in the market) than in the non-invading one. Furthermore, species in the invading group are also sold by more nurseries. Therefore, invading species have had a higher probability of being found in the market in the last century. This may have increased their chances to be planted and, thus, increased their risk from escaping from the garden by an increased propagule pressure. Mulvaney (2001) also concluded that species appearing with higher frequencies in mid-19th century nursery catalogues contributed a higher percentage to the naturalised species pool in south-eastern Australia than species appearing less frequently. However, to our knowledge these results are the first to document these relationships based on historical time-series data of nursery catalogues (1885–2005). 'Popularity' seems, thus, to be a relevant factor to explain the ability of an ornamental non-native plant species to start an invasion process. Policies to increase general awareness of plant invasions, such as education and codes of conduct, as well as screening process for non-native ornamental plants, are therefore an important step to prevent further invasions (Reichard & White, 2001; Bell *et al.*, 2003).

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The spread of *Frankliniella occidentalis* through the UK protected horticulture sector – scales and processes

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ABSTRACT

Western flower thrips (*Frankliniella occidentalis*) entered the UK in 1986 and spread rapidly through the protected horticulture sector. The historical spread is being studied at three spatial scales with each scale presenting different arguments for the spread. The smallest scale is that of movement between individual plants within a glasshouse, predominantly a function of the biological characteristics of the thrips and the crop. The second and third spatial scales relate to the cluster-like structure of the horticulture industry in the UK. Intra-cluster spread is a function of both natural and trade related factors whilst inter-cluster spread is primarily a function of trade. A model of two of the three spatial scales in relation to the recorded spread of western flower thrips from 1986 to 1989 during a statutory campaign to control its spread, and the pests' subsequent establishment in the UK is described. The model can be used to investigate how alternative pest management decisions could have influenced the spread of *F. occidentalis.*

INTRODUCTION

The global spread of western flower thrips (WFT) (*Frankliniella occidentalis*), a significant horticultural pest, began in the late 1970s, having been previously confined to the western coast of North America. The spread across the USA and Europe was almost concurrent, aided by the huge increase in the national and international movement of plant material (Kirk & Terry, 2003). The attribute of polyphagy may also explain the species' remarkable ability to establish and persist in ecosystems throughout the world (Funderburk, 2001). The Great Lakes were reached in the mid 1980s, Florida in 1982, and the Eastern Seaboard in the late 1980s to early 1990s. In Europe, the Netherlands was the first recipient in 1983, with Denmark and Germany being reached in 1985. The growth in quarantine interceptions of thrips (Vierbergen, 1995) suggests that more WFT were being introduced at a time when the rate of successful establishment of insect species was also increasing (Frank & McCoy, 1992; Kiritani, 2001, cited by Kirk & Terry, 2003). The first outbreaks in the UK were recorded in mid-1986 at a UK research institute and separately at a medium-sized chrysanthemum propagating business in the South West of England. It was the second of these outbreaks that facilitated the UK-wide spread of WFT since the propagator shipped plants carrying the pest to clients. In addition, there were several new introductions from overseas in 1987.

It is important to note that the first case involved an outbreak of *tomato spotted wilt virus*, causing significant damage. None of the subsequent outbreaks over the following three years involved the virus. This probably explains the rapid shift in the response from the industry to the perceived threat from WFT, as illustrated in an industry magazine, the Grower, in late 1986. Its editorial of 27th November stated dramatically that "... (*F. occidentalis*) *seems capable of ending life as we know it*". This concern of the destructive potential of the pest altered within a month to a concern of the policy response from the regulator: *"of course you are legally bound to report it but you know the consequences of that course of action – the Plant Health people will descend on you and lay about you with all manner of statutory order ending (for the time being) business life as you know it."* (25th December 1986, editorial). Firms facing such a choice may have opted to try to control privately before alerting Plant Health. This may have been true for the propagator in the South West who informed Plant Health only after four months of attempting private control.

Initially, Plant Health policy was to attempt eradication, but eventually there was broad acceptance within the government regulator that the policy was effectively one of containment, particularly since the propagator had already passed on the pest to dozens of clients. However, growers could clearly see the high costs of temporary business cessation as well as the high probability of re-entry of the pest from Europe (points made vigorously by the industry). Frey (1993) concluded that even under near optimal conditions of chemical pest control, it is unlikely that a glasshouse can be kept pest-free over extended periods. This is due to increased levels of resistance and the high probability of reintroduction after a successful eradication. The private cost elements of national control were borne by a relatively small number of firms.

It seems very likely that the almost 400 officially recorded outbreaks of WFT between mid-1986 and the end of 1989 underestimate the actual spread of the pest. However, archived records for each outbreak, held at the Central Science Laboratory (CSL), are probably the only data-set describing WFT spread during this period. This paper briefly describes part of the ongoing research into the historic spread of WFT around the UK and the implications for public policy responses. It concentrates on the biological-economic interactions that inform spread at different scales of operations.

SCALES AND PROCESSES

The spread of WFT can be viewed as occurring at three separate scales. At the smallest scale, and upon the initial introduction to a UK glasshouse, the pest can spread from plant to plant within the single production unit. Its ability to spread within the glasshouse will influence its effectiveness at moving to other scales. Its ability to spread from plant to plant will be a function of its biological characteristics with respect to the specific host and the management of the glasshouse. The management of the glasshouse can both enhance spread (e.g. movement on workers clothing) as well as act to reduce it (new pest controls).

The second scale of spread involves movement from glasshouse to glasshouse within a cluster of glasshouses. This can be a function of: the type of business and its ownership structure (e.g. retail, production, vertically integrated etc); the proximity of neighbouring glasshouses; the use of casual labour; the existence of suitable habitat between glasshouses etc. In comparison to spread at the smallest scale, the importance of biological characteristics is lessened.

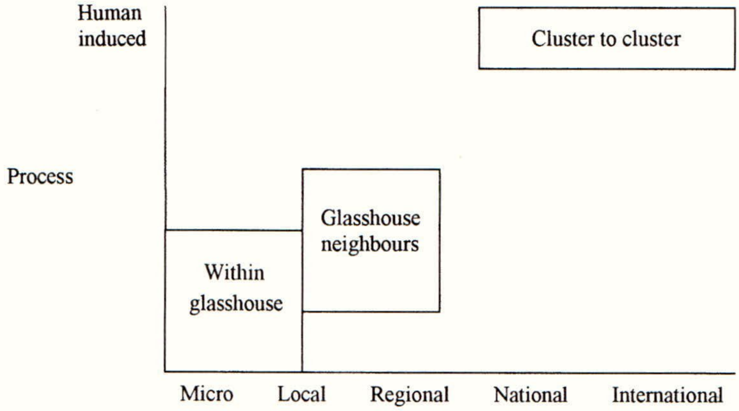

Figure 1. Processes and scales of spread.

The largest scale of spread allows WFT to move from one end of the country to the other in a matter of hours, a degree of spread completely beyond the natural capabilities of the pest. This movement, from glasshouse cluster to glasshouse cluster, occurs within the national trade network and is primarily a function of distance and the number of potential recipients within the cluster.

The movement and spread of WFT thus described can be modelled as an interconnecting series of cellular type landscapes. The movements within each scale result from different processes at work with, in general, the level of anthropogenic input into the movement, increasing as the scale increases. This general relationship between scale and process for a pest entering the horticulture sector is presented in Figure 1. The general approach to modelling adopted is outlined below and two of the three scales are described in more detail.

MODEL STRUCTURE, DATA AND RESULTS

The cellular landscape allows spread to be analyzed in terms of the probability of movements between cells. Generally, the probability of a cell being infested in time t will depend upon the pattern of thrips movement within a defined neighbourhood in time $t\text{-}1$ and the management options taken in time $t\text{-}1$. For focal cell ij:

$$P_{ij}(t) = f(Z_{ij}(t-1), W_{ij}(t-1))$$

Where P_{ij} is the probability of cell ij becoming infested in t, Z_{ij} represents the neighbourhood of ij (defines potential sources), and W_{ij} is a vector of invader-specific management options that impact on ij. The management options included in W also provide potential levers for the environmental authority to affect their decisions, and so to influence the spread in Z. These elements will incorporate the appropriate ecological and economic theory at each scale to illustrate their impact on the rate of spread and the efficacy of the control response.

Scale 1 – Spread within the glasshouse

There is scant literature on the movement of WFT at the glasshouse level. Indeed, any experiment to measure this will be a subset of a very large range of possibilities with variations due to hosts, particular stage of host, number of pests introduced, the current control regime etc. The output required from this level of the model is the amount of stock within a glasshouse that is infested that can be a source of infestation at other scales through general business operations and trade. Data obtained from an Horticulture Research International experiment that sampled WFT counts on *Impatiens* plants suggested a presence/absence pattern similar to that of a Levins metapopulation. Using these data and results from Rhainds & Shipp (2004) on dispersal distances, a cellular automata type model using Levins parameters for colonization and extinction of cell populations was used to predict spread around a glasshouse. This approach allows the measurement of the proportion of infested cells at any one time and thus the proportion of infested shipments.

As mentioned, the outbreak at the propagator in the UK resulted in it shipping WFT to a number of clients. Records of the UK outbreak held at CSL include a list of the propagator's clients that received stock in three time-periods prior to the regulator being made aware of the presence of the pest and introducing statutory control preventing any further movement from the infested site. Each of the approximately 500 clients were visited and the presence or absence of WFT assessed. From this it was possible to estimate the proportion of infested shipments sent out by the propagator as the population of WFT spread through the glasshouses. The basic data from this analysis is presented in Table 1.

Table 1. Number of infested shipments from UK propagator.

	Weeks 19–25	Weeks 26–29	Weeks 30–36
Number of shipments	89	132	265
Number of corresponding infested sites	1	9	56
Estimated number of infested shipments per week	0.14	2.25	8.00
Proportion of infested shipments to total shipments	1.1%	6.8%	21.1%

It should be noted that many of the inspections were made at sites with young plants. A smaller number of second visits to the clients found proportionately more outbreaks per visit suggesting that the table presents under estimates of the proportion of infested shipments. The spread of WFT within the glasshouses of the propagator can be seen in the proportion of infested shipments leaving the site. The propagator became aware they had a problem toward the end of the first period and took (unsuccessful) remedial measures. The regulator was not informed until the end of the third period.

The economic problem at this scale is to maximize profit, which requires that the decision-maker should equate the marginal benefits and marginal costs of control. This determines the optimal combination of control options in the event of an outbreak. Measures taken by Plant Health affect the privately optimal control options by changing the relative costs and benefits of different control options. This feeds back into the parameters for cell colonization and extinction.

Scale 3 – Spread between glasshouse clusters

At this scale the dominant processes involved in the spread of thrips relate almost entirely to the nature of the trading system and the only natural characteristic of interest is the ability to survive in transit. Despite this, it is interesting to note the similarity between models from economics and geography that describe the flow of commodities between regions and incidence function models in metapopulation analysis. Both analyze the flow of species or goods between clusters/habitats as a function of some weight variable (e.g. population/patch area) decayed by distance.

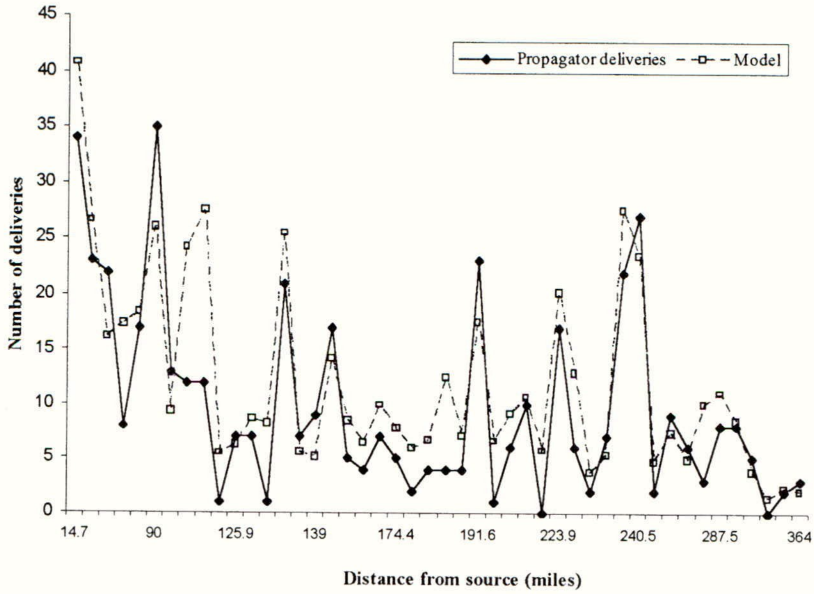

Figure 2. Propagator deliveries against gravity type model.

Further information to be gleaned from the propagator's client list was the location of those clients that had received stock. Recipients of stock could be grouped into relevant clusters, with clusters defined as counties due to the collection of national data at this scale. The attraction between clusters is a function of a variable representing a weight that is decayed by distance. Figure 2 shows the number of deliveries made by the propagator to clusters increasing in distance from the origin along the x-axis. The model involves a fat tail dispersal kernel with the weight variable represented by the number of protected agriculture holdings per county (cluster). In the cellular landscape this is akin to the probability of receiving stock from an infested source. The probability of that shipment being infested is found from the modelling at scale 1. Management of the spread at this scale can only be prevented by controlling the movement of stock within the trade network for a number of key growers either through imposition by Plant Health or self regulation within the industry.

CONCLUSIONS AND FUTURE WORK

The spread of WFT through the UK protected horticulture sector illustrates some of the problems facing the regulating authority with respect to both biological and economic uncertainties. The approach outlined here formally recognizes and addresses problems caused when analyzing invasion episodes; specifically that the spread is occurring at several scales and processes concurrently, with different processes dominating at different scales. Whilst the model remains to be fully developed it offers a number of insights that, in addition to the analysis of the WFT outbreak archive. We find that the dominant process at each scale is the primary control option taken. The scale at which statutory policy is directed depends on when the regulator becomes aware of the pest. For the case of WFT in the UK, Plant Health became aware of its presence in the commercial sector only when spread was occurring at scale 3.

Future work will address the following kind of questions: 1) What are the implications of imposing high private costs on a small number of growers for national control?; 2) If the regulator becomes aware at a fairly late stage, does an eradication policy impose costs that are greater than benefits?; 3) Can collective private insurance type schemes affect rates of spread?

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Quality management systems as a solution for the control of spread of alien species

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ABSTRACT

One of the many risks in the plant production and international plant trading businesses is the spread of alien species. Businesses know that they not only sell products, but also their business image. The spread of alien species is also an image problem for a companies and traders. Two non-governmental systems exist world-wide, which were used by businesses and which are implemented for sustainable development, based on quality management systems and/or different criteria systems. These systems must be use in the future against the spread of alien species, because this is one part of sustainability in quality production. Also, quality production is primarily the responsibility of the business.

INTRODUCTION

The spread of alien species is due mainly to increasing international trade. International trade, therefore, carries a large part of the responsibility for the protection of food and the environment, and for societal safety. Trade and production have created private international quality management and environmental criteria systems for quality controls, and private certifiers already visit the businesses to inspect these. Private systems, therefore, exist, so it should be possible without involving too much effort to clearly reduce the problematic spreading of alien species.

FUTURE-ORIENTED BUSINESSES AND SUSTAINABLE PRODUCTION

Economical performance assessment, based on economically relevant parameters such as cost-benefit calculations or financial statements, is a matter of course in all areas of the economy and in all businesses. For many businesses, this knowledge is no longer sufficient to manage a business successfully in the long term.

Future-oriented businesses want to know:

- how sustainable is my production, provision of services and product?
- how can I evaluate sustainable activities?
- how credible is an evaluation of sustainability?

Can sustainability be communicated in a credible manner?

For image reasons, businesses want to know how sustainable their businesses are.

Businesses know that they not only sell products, but also their business image. It takes a long time to build-up a positive image, and it is extremely costly. Credibility and, subsequently, the business's image can be destroyed in next to no time by the Internet. Image is a precious part of a business's capital. The spread of alien species is also an image problem for a company, and also a major risk.

NON-GOVERNMENTAL SYSTEMS AND PHYTOPATHOLOGICAL RISKS

Ecological sustainability includes the minimisation of phytopathological risks. Two different systems exist world-wide, which were used by businesses and which are implemented for sustainable development (Meier, 2002a). In the past 10 years, agricultural businesses have used:

- non-governmental quality management;
- non-governmental criteria systems.

The focus is on product quality and the quality of production (Meier & Feldmann, 2003). These systems must be used in the future, because the spread of alien species is one part of sustainability in quality production. Also, quality production is primarily the responsibility of the business.

INTERNATIONAL MANAGEMENT SYSTEMS

In order to document and communicate the ecological achievements of a business, instruments such as environmental management systems are used. Many businesses work with environmental management systems, for example ISO 14001 (1996). The EC-Eco-Audit Ordinance or European Management Audit Scheme (EMAS II, 2001) has the same aim. Such systems make it is easy to include a pest and disease assessment for export businesses. Management systems such as ISO 14001 have the advantage that they can be implemented world-wide and throughout different sectors. Not only do many agricultural businesses use ISO 14001 but the packaging industry does likewise. The spread of alien species also effects all sectors. An existing, international system created by businesses can, thus, be used for preventing the spread of alien species.

However, ISO 14001 is different from EMAS II. The main differences between ISO 14001 and EMAS II are that the former allows free agreements concerning the world economy, a certificate is issued; also, ISO 14001 is compatible with ISO 9000.

Compared with ISO 14001, EMAS II represents a legal procedure in the EU. An environmental declaration must be published and EMAS supplies a logo for advertising purposes. Furthermore, environmental achievements are measured directly.

The aims of ISO 14001 and EMAS II are the continual improvement of environmental protection. Environmental protection as a management task. The avoidance of environmental pollution, however, comes within the aims of environmental protection. However, plant protection products can stress the environment. Therefore, the plants and alien species must be observed and/or controlled in their home environment, in the agricultural business. Observance and control is a task for business management. Features of ISO 14001 and EMAS II are as follows:

ISO 14001	EMAS II
• Free stipulation of the world economy • Issuance of a certificate • Comparability with ISO 9000	• EMAS LOGO for advertising • Publication of an environmental declaration • Legal procedure of the European Union • Assessment of environmental achievement

INTERNATIONALLY IMPORTANT SYSTEMS FOR AGRICULTURAL ON THE BASIS OF CRITERIA

The most important criteria in this system are the criteria of plant protection, but these do not include any reference to alien species. In this regard, it is important to complete the critaria lists of the following systems:

International environmental criteria systems in agriculture
• Euro-Retailer Produce Working Group of Good Agricultural Practice (EUREPGAP) • Flower Label Program (FLP) • Milieu Project Sierteelt (MPS) • Forest Stewardship Council (FSC) • Pan European Forest Certificate (PEFC) • Rainforest Alliance (RA) • Comiteé de Liaison Europe-Afrique Caraibes Pacifique (COLEACP)

Euro-Retailer Produce Working Group of Good Agricultural Practice (EUREP GAP)

EUREP GAP (www.eurep.org) is a co-operation of numerous leading retail enterprises in Europe. EUREP trading concerns will make fruit, vegetable and flower producers discharge their duties, which means they should produce goods only in line with pre-determined consumer protection, environmental protection and social criteria, and have these conditions of production checked by an independent private enterprise. The producers have to be oriented according to EUREPGAP criteria. This aims at getting the entire food chain from agricultural production to the consumer under independent control (Meier, 2002b). In responding to the demands of consumers, retailers and their global suppliers, EUREP has created and implemented a series of sector-specific farm certification standards. The aim is to ensure integrity, transparency and harmonisation of global agricultural standards. This includes the requirements for safe food that is produced whilst respecting worker health, safety and welfare, and also environmental and animal welfare issues.

Flower Label Programme (FLP)

FLP (www.fian.de) is the result of international discussions about environmentally and socially compatible flower production. It is based on the international 'Code of Conduct for Socially and Environmentally Compatible Production of Cut Flowers', which lays down certain minimum standards. The code of conduct is supervised by the FLP Directorate, which is shared equally by business representatives (producers and distributors), trade unions and non-governmental organizations.

Milieu Project Sierteelt (MPS)

MPS (www.st-mps.nl) is an environment programme for ornamental plants. MPS was set up, as a foundation, in 1995 by Dutch ornamental plant merchants, and aims at minimising environmental pollution in the ornamental plant nurseries involved. MPS is a system with controllable environmental criteria, based on voluntary registration and environmental testing. Social criteria were introduced, additionally, on the basis of the requirements laid down in SA 8000. This programme includes not only horticultural enterprises but also retailers.

Forest Stewardship Council (FSC)

The FSC (www.fsc.de) was set up in Toronto, Canada, in 1993 by environmental organisations, representatives of ethnic groups concerned by large-scale timer production, and by representatives of forest industries. The FSC wants to achieve, on a global scale, forest management which is both economically buoyant and compatible with nature and human society. The organisation has created a 'quality seal' for wood, which is recognised in the world market. FSC certification is guided by ten principles, with 56 criteria.

Pan European Forest Certificate (PEFC)

The PEFC Council (Programme for the Endorsement of Forest Certification schemes) (www.pefc.de) is an independent, non-profit, non-governmental organisation, founded in 1999, which promotes sustainably managed forests through independent third-party certification. The PEFC provides an assurance mechanism to purchasers of wood and paper products, that producers are promoting the sustainable management of forests. The PEFC certificate is awarded to forest companies only if they are following guidelines of sustainable forest management and will allow inspections for fulfilment of environmental and social criteria.

PEFC has in its membership 30 independent national forest certification schemes. To date, 17 of these have been through a rigorous assessment process, involving public consultation and the use of independent consultants to provide the assessments on which mutual recognition decisions are taken by the membership. These 17 schemes account for over 57 million ha of certified forests, producing millions of tonnes of certified timber to the market place; this makes PEFC the world's largest certification scheme. The other national members' schemes are at various stages of development, and are working towards mutual recognition under the PEFC processes.

Rainforest Alliance (RA)

A number of agricultural producers in Latin America let their farms voluntarily be tested by the environmental organisation RA (www.rainforest-alliance.org), for fulfilment of social and environmental criteria. Based in New York City, with offices throughout the USA and worldwide, the RA is working in 53 countries. The mission of the RA is to protect ecosystems (and also the people and wildlife that depend on them) by transforming land-use practices, business practices and consumer behaviour. Companies, cooperatives and landowners that participate in the RA-programmes meet rigorous standards that conserve biodiversity and provide sustainable livelihoods. Companies which have successfully undergone such examination may label their products with the 'ECO-OK' label. The crops certified by the RA are bananas, cacao, citrus fruits, coffee, flowers and ornamentals.

Comiteé de Liaison Europe-Afrique Caraibes Pacifique (COLEACP)

COLEACP (www.coleacp.org) is an inter-professional association of exporters, importers and other stakeholders for trading horticultural products with ACP states. The proposed COLEACP criteria are remarkable, because of their extraordinary volume and detail (containing not only ecological but also comprehensive social criteria). This proposal of the EU working group is also based on comprehensive lists of criteria, with a view to Good Agricultural Practice, as follows:

Main areas of evaluation for criteria systems in plant growing
• Description of environmental politics
• Location description
• Documentation
• Soil care and substrate treatment
• Water management
• Crop rotation
• Fertilisers and fertiliser techniques
• Plant protection (including alien species) and plant protection techniques
• Waste management
• Energy
• Nature / landscape / water protection
• Hygiene
• Advanced training

CONCLUSIONS

Responsibility for the spread of alien species must be made clear to traders. The business is primarily responsible for goods which are in perfect condition. The State is only second in the line of those responsible, with its legal standards and inspections. The principle of the originator counts! It is not fair that the profit from global trade is privatized and the risks on the other hand are socialized.

Trade and production businesses have created private international quality management and environmental criteria systems for quality control, but these must be used and extended. It should be possible, without involving too much effort, to reduce the problematical spreading of alien species. However, the State alone will not be able to solve this problem in a sustainable and credible manner. Plant health, the government, traders and trading organizations must work more closely together in the future. A trans-disciplinary approach is essential, because the trading of fresh goods is a very fast global business.

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The current status of *Phytophthora ramorum* in Austria

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ABSTRACT

Since the middle of the 1990s, symptoms of wilting in plants of *Rhododendron* and *Viburnum* were quite often observed in tree nurseries of Germany and the Netherlands. At approximately the same time a new fatal phenomenon in several oak species, named sudden oak death, was recorded in the USA. In 2001 this new pathogen was described as *Phytophthora ramorum*. Since 2002, monitoring has been carried out in the member states of the European Union. At first this new *Phytophthora* species was found mainly on *Rhododendron* (except *R. simsii*) and *Viburnum*, but now many hosts are known, including *Arbutus* sp., *Camellia japonica*, *Hamameils virginiana*, *Kalmia latifolia*, *Leucothoë* sp., *Pieris formosa var. forrestii*, *P. japonica*, *Syringa vulgaris* and *Taxus baccata*. In 2004, even trees such as *Aesculus hippocstanum*, *Castanea sativa*, *Fagus sylvatica*, *Quercus cerris*, *Q. ilex* and *Q. falcata* were infected. In the 2004 monitoring programme, 447 visual inspections in tree nurseries, garden centres and in the public green were carried out in Austria. In all federal states, samples were taken from forests and windbreaks in which susceptible trees such as *Aesculus hippocstanum*, *Castanea sativa*, *Fagus sylvatica*, *Pseudotsuga menziesii*, *Quercus cerris*, *Q. petraea*, *Q. robur*, *Q. rubra* and *Taxus baccata* were present. However, none of the examined plants was infected by *Phytophthora ramorum*.

INTRODUCTION

Since the middle of the 1990s, symptoms of wilting in plants of *Rhododendron* and *Viburnum* were quite often observed in tree nurseries of Germany and the Netherlands. At approximately the same time a new fatal phenomenon in several oak species, named sudden oak death, was recorded in the USA. Neither the pathogen which was found in the tree nurseries causing wilts nor the one which caused sudden oak death in the USA was known at this time. In 2001 a new *Phytophthora* species, described as *Phytophthora ramorum* (Werres *et al.*, 2001) was identified as the causal agent. A short time later it was clear, that this pathogen also was responsible for the dying of the oak trees in the USA.

P. ramorum belongs to kingdom Chromista and is classified as an Oomycete (water mould). Similar to other water moulds, *P. ramorum* requires a moist environment for active growth and reproduction. The spores of the fungus are found on leaf surfaces of the susceptible plants. Windblown rain and contaminated soil serve in transmission of the fungus from one plant to another. As *P. ramorum* belongs to the heterothallic phytophthoran species, different mating types occur. Early analyses showed that, initially, only mating-type A1 was found in Europe and only mating-type A2 in the USA, whereas now A1 and A2 mating types can be detected both in Europe and in the USA. The geographical origin of P. ramorum is still unknown, but it is possible that it may have originated somewhere in Asia, more specifically, in northern Yunnan Province in the People's Republic of China, because rhododendrons and azaleas are abundant there, and the climatic conditions in this part of the province correlate well with those predicted to be favorable for the pathogen.

THE OCCURRENCE OF *PHYTOPHTHORA RAMORUM* IN EUROPE

Since the beginning of the monitoring programmes, carried out in the member states of the European Union, this pathogen could be detected in more and more countries and even on more and more different plants. Germany, the Netherlands and the UK were the first countries which notified the occurrence of this pathogen. Subsequently, this pathogen was found in Belgium, Denmark, France, Ireland, Norway, Switzerland and Spain. During the early years mainly *Viburnum* spp. and *Rhododendron* spp. (except *R. simsii*) were infected, but since 2003 shrubs such as *Arbutus* sp., *Camellia japonica*, *Hamameils virginiana*, *Kalmia latifolia*, *Leucothoë* sp., *Pieris formosa* var. *forrestii*, *P. japonica*, *Syringa vulgaris* and *Taxus baccata* came up with this disease. In 2004 this pathogen was isolated even from trees such as *Aesculus hippocstanum*, *Castanea sativa*, *Fagus sylvatica*, *Quercus cerris*, *Q. petraea*, *Q. robur* and *Q. rubra*. Now there are no longer significant differences between host plant ranges in Europe and the USA (*Acer macrophyllum*, *Aesculus californica*, *Arbutus menziesii*, *Arctostaphylos manzanita*, *Camellia* sp., *Hamamelis virginiana*, *Heteromeles arbutifolia*, *Lithocarpus densiflorus*, *Lonicera hispidula*, *Pieris* sp., *Pseudotsuga menziesii*, *Quercus agrifolia*, *Q. chrysolepis*, *Q. kellogii*, *Q. parvula* var. *shrevei*, *Rhamnus californica*, *Rhododendron* sp., *Rosa gymnocarpa*, *Sequoia sempervirens*, *Trientalis latifoglia*, *Umbellularia californica*, *Vaccinium ovatum* and *Viburnum* sp.).

Besides the increase in number of natural hosts, there is also another development that gives cause for concern. The first discoveries of this new disease always occurred in tree nurseries,. However, this pathogen is now found in public parks, in private gardens and in the natural environment, especially in the UK, the Netherlands and Germany. In these countries high humidity and moderate temperatures give excellent conditions for survival and spread of the pathogen.

THE OCCURRENCE OF *PHYTOPHTHORA RAMORUM* IN THE USA

Since 1995, *P. ramorum* is found mainly in the central coastal areas of the Californian counties of Alameda, Contra Costa, Humboldt, Los Angeles, Marin, Mendocino, Monterey, Napa, San Mateo, Santa Clara, Santa Cruz, Solano and Sonoma, as well as in Oregon (County of Curry). In these areas, extensive fatality of trees, especially oaks (*Quercus agrifolia*, *Q. kelloggii*) and tanoak (*Lithocarpus densiflorus*) are observed. However, many other plant species can become infected, and they help spread the disease. One of the most important plants in this case is the Californian bay laurel (*Umbellularia californica*). *P. ramorum* has also been found in Florida, Georgia and Washington.

THE CURRENT SITUATION IN AUSTRIA

To date, there has been no record of *Phytophthora ramorum* in Austria. One of the most important reasons might be the climate. In Austria, warm and dry summers and cold winters predominate. Thus, climatic conditions do not correlate well with those predicted to be favourable for this pathogen. An aggravating factor is that in most parts of Austria the conditions are not suitable for growing plants such as *Camellia*, *Pieris* or *Rhododendron*. Growing these shrubs is usually very difficult and, in spite of all efforts, plants often die of black frost, lack of water or too high lime content in the soil. At present, the occurrence and establishment of *P. ramorum* could be expected surrounding areas of Lake Constance (Vorarlberg), because of this area's mild and humid climate. Among plant species favoured for horticultural purposes, species of *Syringa*, Taxus and/or *Viburnum* would be the most likely to become infected by *P. ramorum*. In forests, plants such as *Aesculus hippocstanum, Castanea sativa*, *Fagus sylvatica*, *Pseudotsuga menziesii*, *Quercus cerris*, *Q. petraea*, *Q. robur*, *Q. rubra* and several species of *Vaccinium* are known as susceptible. If the pathogen eventually adapts to dryer climatic conditions and establishes itself in Austrian forests, severe damage may occur to such plants.

In 2004, 447 visual inspections were carried out in tree nurseries, garden centres and in public parks in Austria. In total, 106 inspections were conducted in tree nurseries and 341 in public parks or private gardens. Thirty-six plants from tree nurseries and six from public parks showed *Phytophthora*-like symptoms and were tested in the laboratory (isolation, PCR) for *P. ramorum*. No samples tested positive for *P. ramorum*. Most of the damage on *Rhododendron* and *Viburnum* was caused by non-parasitic agents or by pathogens such as *Botrytis cinerea*, *Pestalotiopsis guepini* or *Phyllosticta* spp.; *Phytophthora citricola* was isolated from two of the rhododendron samples.

To check possible immigration of *P. ramorum* in Austria, samples were also taken from forests and windbreaks in each federal state in which susceptible trees such as *Aesculus hippocstanum*, *Castanea sativa*, *Fagus sylvatica*, *Pseudotsuga menziesii*, *Quercus cerris*, *Q. petraea*, *Q. robur*, *Q. rubra* or *Taxus baccata* occur. These areas were examined visually for typical symptoms of infection with *P. ramorum*, e. g. wilted shoots, pale green to dark brown leaves or parts of leaves, burgundy-red to black sap oozing (bleeding) on the bark surface or flattened cankers. Other species of trees were examined when they showed typical symptoms of an infection with *Phytophthora*. During the entire 2004 season the following plant numbers were inspected:

Aesculus hippocastanus	252	*Quercus cerris*	153
Castanea sativa	163	*Quercus petraea*	441
Douglasia	30	*Quercus robur*	579
Fagus sylvatica	868	*Quercus rubra*	45
Fraxinus excelsior	205	*Taxus baccata*	34
Morus alba	5	*Vaccinium corymbosum*	20
Populus tremula	1	*Viburnum* sp.	403

Laboratory analysis was conducted on a total of 38 samples: *Aesculus hippocstanum* (2), *Castanea sativa* (2), *Fagus sylvatica* (13), *Morus alba* (1), *Populus tremula* (1), *Quercus cerris* (1), *Q. petrea* (2), *Q. robur* (4), *Q. rubra* (2), *Taxus baccata* (3), *Vaccinium corymbosum* (3) and *Viburnum* sp. (4). All examined plants were *P. ramorum* negative. In some cases infections with various *Phytophthora* species were detected (all of which were known to be common in Austria).

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Pest risk analysis in Europe – how can risks of invasive alien species be assessed and managed?

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ABSTRACT

Pest risk analysis (PRA) is a tool used in plant health to assess risks of quarantine pests or other organisms harmful to plants and to identify options for their management. Standards of the International Plant Protection Convention (IPPC) and the European and Mediterranean Plant Protection Organisation (EPPO) are available to facilitate the procedure of PRA. Recent amendments of these standards allow a better analysis of risks posed by plant pests to biodiversity and the environment. By this, the regulation of species that threaten biodiversity (invasive alien species) can be technically justified according to the Sanitary and Phytosanitary Agreement under the World Trade Organisation. At present, in particular risks of invasive alien plants are in the focus of adapting PRA in Europe. There are several differences between the assessment and management of pests directly harmful to cultivated plants and pests threatening biodiversity or the uncultivated environment. In many cases, the identification of (potential) invasiveness is very difficult. For the assessment of economic importance of environmental risks, several methodologies are provided that differ from the conservative economic assessment. In contrast to the 'traditional plant pests', which are introduced unintentionally, alien plants are usually introduced intentionally. Planting them into intended habitats usually does not pose any problems, only very few species spread into unintended habitats and have adverse effects. For selection of management options a differentiated approach is necessary, including the prohibition of introduction of significantly risky plants and the obligation for specified requirements to restrict their spread.

INTRODUCTION

In phytosanitary systems, pest risk analysis (PRA) focuses on the question, whether the assessed organism should be regulated. As a basic requirement for PRA, the criteria for the definition of 'plant pest' (IPPC, 1997) have to be satisfied concerning the relevant organism. Subsequently, the risk of introduction and spread of this pest is assessed and – if appropriate – options for measures are evaluated. Since the existence of such PRAs, impacts on the environment were considered basically but not studied in detail, and until recently, effects of plant pests on wild flora, habitats and ecosystems have not been in the focus. However, a closer look at the scope of the International Plant Protection Convention (IPPC) reveals, that the Convention's aim is the protection of plants, without any restriction. Also habitats and ecosystems are protected from the consequences that the introduction of plant pests may have, as they are essential for the survival of plants. Thus, the IPPC is also applicable to invasive alien species harmful to plants – but what is the difference between these invasive alien species and quarantine pests?

By definition (CBD, 2002), invasive alien species are non-indigenous organisms that threaten biodiversity. Consequently, an organism, that solely poses a risk to crops/cultivated plants is not an invasive alien species and 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, 1997), 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 both the definition for an invasive alien species and a quarantine pest. This is based on the IPPC interpretation that 'economic importance' in the definition for quarantine pest includes environmental importance. 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 (see also International Standard on Phytosanitary Measures (ISPM) No. 5, Supplement No. 2, 2003).

To provide a tool for the conduction of PRA on an internationally harmonized basis, the IPPC has adopted two pest risk analysis standards in 1996 (ISPM No. 2 'Guidelines for pest risk analysis') and 2001 (ISPM No. 11: 'PRA for Quarantine Pests'). Both are focussing mainly on the unintentional introduction of pests of cultivated plants. Based on these standards, the European and Mediterranean Plant Protection Organization (EPPO) developed a risk assessment scheme in 1997, and a risk management scheme in 2000. These EPPO standards were designed as user-friendly schemes to facilitate the conduct of PRA, but, since they are based on the IPPC Standards, PRAs done with these schemes also provide technical justification for the regulation - as far as necessary - of these organisms by states in the EPPO region. This is in accordance with the SPS-Agreement (1994) of the World Trade Organization. The IPPC-Standards are available at the IPPC website (International Phytosanitary Portal): www.ippc.int., the EPPO-Standards at the EPPO homepage (www.eppo.org).

Following the activities of the Convention on Biological Diversity (CBD) and the IPPC (see e.g. Schrader & Unger, 2003), ISPM No. 11 and the EPPO standards have been revised to address the effects of quarantine pests on biodiversity and environment in detail. The revision of ISPM No. 2 has started recently. A supplement to ISPM No. 11 was adopted in 2004 as ISPM No. 11: "Pest risk analysis for quarantine pests including analysis of environmental risks and living modified organisms" (supplementary text concerning environmental risks is marked by 'S1'). It was developed following statements of the Interim Commission on Phytosanitary Measures concerning invasive alien species (ICPM, 2001). By this, also "risks affecting uncultivated/unmanaged plants, wild flora, habitats and ecosystems within the PRA area" are included into the standard, and it is clarified 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" (ISPM No. 11, 2004). This article will provide an introduction to the assessment and management of invasive alien species in the framework of plant health.

ENVIRONMENTAL RISK ASSESSMENT

From a traditional pest, it is usually known before that it is able to cause damage, at least somewhere and under certain conditions. In particular for alien plants, the potential to cause damage is much more difficult to evaluate and to quantify. One of the challenges to assess the risks of alien plants is the identification of the plant's potential for invasiveness. The assessment of the consequences of the establishment and spread of a plant pest affecting uncultivated/unmanaged plants or wild flora is quite different from that of a plant pest affecting cultivated plants. Also, the approach to the economic impact assessment is different. Unintentional introduction, the traditional pathway for plant pests, is in this context less important than intentional introduction. In particular for alien plants for planting, the assessment of their entry is not relevant, but it is important to look at the pathway from the intended to the unintended habitat and the probability of establishment in the unintended habitat.

Assessment of establishment and spread

Several points or questions in the PRA standards deal with the assessment of establishment and spread of an introduced organism, considering climatic and other abiotic factors that would affect pest establishment, possible prevention of establishment by competition from existing species in the PRA area or by natural enemies, likelihood of eradication or control of the species after introduction, adaptability of the pest, speed of natural and human assisted spread, and how often the pest has been introduced into new areas outside its original range. The reproductive strategy and duration of the lifecycle of the assessed species is another important point, taking into account characteristics which would enable the pest to reproduce effectively in a new environment, such as self fertility, short lifecycle, number of generations per year, resting stage, vegetative propagation, etc.

Assessment of invasiveness

In particular in the case of alien plants, it is necessary to find out if the assessed organism has intrinsic attributes that indicate that it could cause significant harm to plants or plant communities. Attributes, which could be relevant for invasiveness are a broad ecological amplitude, the ability to build up a persistent seed bank and to produce many seeds or vegetative propagules, and a high competitive strength. Important questions are if the species is invasive in its native range or elsewhere, if the propagules are highly mobile or if the plant does benefit from cultivation or browsing pressure, and if there is a likelihood of building up monospecific stands etc. The prediction of invasiveness of an assessed plant will probably, in many cases, be the most difficult point in the whole PRA. Several publications deal with the prediction of invasiveness and the related difficulties (e.g. Kolar & Lodge, 2000; Williamson, 2001; Heger & Trepl, 2003). The success of a plant in invading a certain area will also depend on the invasibility of the unintended habitat, so this will have also to be assessed.

Consequences of establishment and spread

An important part of PRA is the assessment, which effects or consequences the establishment and spread of a pest would have in the considered area. At first, direct effects or primary consequences have to be evaluated. For environmental risks, important consequences would be for example the reduction of the abundance of keystone plant species, of plant species that are major components of ecosystems or of endangered native plant species. Also, protection of other plant species against significant reduction, displacement or elimination is provided, though endangered species receive more attention than just 'normal' species because of their status.

Keystone plant species, which are 'responsible' for the existence of an ecosystem of a certain type, and species that are major components of ecosystems are of particular relevance, because any reduction of their abundance will certainly change the habitat or ecosystem that is dependent on them, or even cause the ecosystem to collapse. The effect of such species is disproportionately large compared to the species' abundance. An important keystone species in European forests is *Pinus sylvestris*. In the forest biocenosis it can play a critical role, it has relationships with many plants and animals and it affects resource availability (Chapin *et al*., 1997). *P. sylvestris* is very susceptible to the pinewood nematode *Bursaphelenchus xylophilus* (Evans *et al*., 1996). Another keystone species is the European beech, *Fagus sylvatica*. Experiments and detection in the natural environment have shown that this species is susceptible to *Phytophthora ramorum* (Brasier *et al*., 2002; EPPO, 2005). Research on both of these invasive alien species is currently done in different EU projects, adding valuable information to the assessment of risks and to economic (including environmental) impacts.

Examples for indirect pest effects or 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 processes 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, *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 a nitrogen enrichment in the soil caused by this tree species. This has a significant negative impact on nutrient-poor soils, which often are habitats for endangered plant species. A different kind of example is the damage which could be caused by the aquatic plant *Crassula helmsii*. Its vegetative growth leads to dense mats which can block ponds and drainage ditches. The mats can be dangerous to pets, livestock and children who mistake them for dry land.

Assessment of economic consequences

For a valuation of the environment, the supplement of 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). For the assessment of these values, methods exist referring to market-based approaches, surrogate markets, simulated markets, and benefit transfer. It is also possible to base the assessment on non-monetary valuations (number of species affected, water quality), or expert judgement, if it follows documented, consistent and transparent procedures.

Pathways

With the supplemented ISPM No. 11, it is not only possible to assess the risk of unintentional introductions of (for example) seeds or other propagules contaminating imported commodities but also of intentional introductions of plants for agriculture and forestry or for horticultural and other ornamental purposes. In the case of imports of such plants for planting, an assessment of the probability of entry would be redundant, as the movement of the plant into a country and subsequently into a certain area is intended. Instead, it is very important to consider the pathway(s) from the intended habitat, e.g. the garden, the field, the park, to the unintended habitat. It is very likely, and often even promoted, that the plant establishes in the intended habitat, but its escape into an unintended habitat and its subsequent establishment and spread may not be desirable and may cause severe problems. Though this will not be the case for most plants, there is still a risk which can be expressed by the 'tens rule' (Williamson, 2001), which states that 10% of introduced species spread, 10% of these establish, and 10% of the established species cause problems (= 0.1%). PRA is very important to identify these few species.

ENVIRONMENTAL RISK MANAGEMENT

Uncertainty

The level of uncertainty is often greater in the assessment of environmental risks than in risks to cultivated plants, owing 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 and should be designed in proportion to the risk. For the identification of management options (see below) it is important to consider the degree of uncertainty. In case of intentional introduction of plants with a high level of uncertainty regarding pest risk it may be more appropriate not to take phytosanitary measures at import, but to apply surveillance or other procedures after entry. Also, the phenomenon of 'time lag' has to be considered – some invasive species, especially plants, show invasive behaviour after a certain time only.

Management

In particular, management options for intentionally introduced plants are different from management options for traditional pests. ISPM No. 11 does not give detailed guidance on how to proceed with invasive or potentially invasive plants. In the framework of EPPO, it is therefore currently discussed to develop a standard for the import of alien plants. Important points to consider are: the raising of public awareness, 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 habitat, prohibition of planting in unintended habitat, required growing conditions for plants), the notification before import, restrictions on movement (e.g. prevention of movement to specified areas), the obligation to report findings.

CONCLUSIONS

For all organisms threatening plants or plant products, directly or indirectly, the revised IPPC and EPPO standards on PRA provide the necessary elements for a substantial risk analysis. The experience for their application and implementation with regard to environmental risks has yet to be increased. European plant protection organisations should follow the revised IPPC PRA standard, and are encouraged to make use of the adapted EPPO PRA scheme for the assessment and management of invasive alien species.

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Invasive pathogens – from Dutch elm disease to sudden oak death

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ABSTRACT

Fungal pathogens can cause long-term damage to trees, and changes in forestry management may even increase the susceptibility of trees to some diseases. However, a consequence of growing global trade and travel is the increased opportunity for introduction of previously unknown pests and pathogens into new geographical regions. One of the best known examples is Dutch elm disease, caused by two closely related fungal species, *Ophiostoma ulmi* and *O. novo-ulmi*. Both pathogens have killed millions of elms throughout the Northern Hemisphere in two pandemics spanning the 20th century. Much more recently, populations of riparian and shelterbelt alders across Europe have come under threat from another new pathogen: *Phytophthora alni*. This pathogen has arisen as a result of a recent hybridization event between two well-known species of *Phytophthora*. Over the past decade, *P. alni* has established along river systems in 12 European countries, killing many trees in the process. Yet another new *Phytophthora* species now threatens a wide range of tree genera and also many ornamental and understorey plants. Identified as the cause of sudden oak death in USA in 2001, this previously unknown species *P. ramorum*, has now been found in 14 European countries, including the UK, but is currently most damaging in the USA, notably California. Based on its behaviour, *P. ramorum* has the potential to be another highly invasive pathogen, although many factors will play a role in the process.

INTRODUCTION

Some fungal pathogens are capable of causing long-term damage to trees, accompanied by serious economic losses and environmental damage. The potential to cause damage can be exacerbated by changes in forestry management and silvicultural practices, especially if they have the unintentional effect of increasing the susceptibility of trees to endemic diseases. However, one consequence of the vast international movement of people and traded goods is the hugely increased opportunity for accidental introductions of previously unknown pests and pathogens into new geographical regions. Released from hosts and habitats where they may have evolved over millennia, some pathogens have proved to be highly invasive and devastating disease-causing organisms.

What makes an invasive pathogen?

One of the most fascinating questions facing us is what causes forest pathogens to become damaging and widespread. The trigger is often change. Environmental changes created by modern forestry practice, such as thinning and clearfell, generating uniformly aged plantations or using monocultures of a single species or provenance, can all exacerbate certain diseases. The increased incidence in the last 30–50 years of black stain root disease (caused by *Leptographium wageneri* on the west coast of North America) and root and butt rot disease (caused by *Heterobasidion annosum* in Europe) both typify this process. However, a major impetus for invasive behaviour can be escape from a native habitat, followed by exposure to hosts without co-evolved resistance mechanisms to combat the new threat. If the newly introduced pathogen then becomes associated with a vector – and this can include man – the vector activities can be highly effective at moving the pathogen over long distances. More recently, we have come to recognise that exposing pathogens to new environments and disturbance almost inevitably leads to genetic change and adaptation. Indeed, without this, rapid extinction is likely for most newly introduced pathogens. Introductions may also bring together related, but previously geographically isolated, pathogen species which may then hybridize, offering opportunities for rapid evolution and the emergence of entirely new and destructive pathogens (Brasier, 2001).

DUTCH ELM DISEASE

This disease is one of the best-known examples of what can happen when a highly invasive and aggressive pathogen is accidentally introduced into a susceptible host population. Over the past century there have been two pandemics of Dutch elm disease, caused by the closely related species of Ascomycete fungi, *Ophiostoma ulmi* and *O. novo-ulmi* (Brasier, 1991). These pathogens have killed many millions of elms as they spread throughout the Northern Hemisphere, and the continuing impact of this disease remains visible in the landscape of many countries.

Dutch elm disease was first observed in Europe during the First World War and the causal agent identified as *Ceratostomella* (now *Ophiostoma*) *ulmi*. During the 1920s and 1930s, the disease killed many trees, and the accidental introduction of *O. ulmi* into North America saw a further explosion in tree deaths as the native American elm (*Ulmus americana*) proved to be even more susceptible than European elm species (Peace, 1960). However, the second pandemic of Dutch elm disease, first recognised in the UK in the early 1970s, proved to be a caused by a new, very different and much more aggressive Dutch elm disease pathogen, *O. novo-ulmi*; previously, it was thought that Europe and America shared the same species of elm disease pathogen. Tracing the source of this new pathogen in North America raised two possible explanations for the emergence of *O. novo-ulmi*. Either a major genetic change had occurred in *O. ulmi* as it spread across the American continent or another Dutch elm disease pathogen had been introduced into the same area but its more aggressive nature had been masked by the impact of *O. ulmi* in the highly susceptible American elm populations.

Ecological genetic studies, aided by modern molecular techniques, have shown that *O. ulmi* and *O. novo-ulmi* are anciently divergent species, probably coming from different locations in Asia (Brasier & Mehrotra, 1995). *O. novo-ulmi* does indeed originate from an introduction into North America, but as a quite separate introduction from the 1930s introduction of *O. ulmi* from Europe. Since then, incidents of hybridization and genetic introgression between *O. ulmi* and *O. novo-ulmi* have created the North American subspecies (*O. novo-ulmi* ssp. *americana*), and it is this new form of *O. novo-ulmi* which has effectively eradicated most mature elms from many western European countries. In eastern Europe and central Asia, another genetically distinct Eurasian subspecies of *O. novo-ulmi* (ssp. *novo-ulmi*) has caused similar levels of damage. This Eurasian subspecies was probably the second Dutch elm disease pathogen to be introduced into North America, and in this melting pot it eventually gave rise to *O. novo-ulmi* ssp. *americana*. As *O. novo-ulmi* has migrated across the Northern Hemisphere in the past 30-40 years, it has rapidly replaced *O. ulmi*, leading to virtual extinction of the latter. Now the two *O. novo-ulmi* subspecies have started their own process of hybridization and genetic exchange, underlining once again the flexibility and dangerous potential of some invasive pathogens.

Clearly, many features have contributed to the success of the Dutch elm disease pathogens as invasive organisms, but three factors have probably been critical. Firstly, these escaped pathogens have been introduced into new host populations which are, with few exceptions, highly susceptible to Dutch elm disease. Secondly, long-distance movement of the pathogens has been aided very effectively by man via the trade and movement of infected material, and on a local scale by numerous species of beetle vectors within the family Scolytidae (Webber, 2004). These beetle species are closely associated with the genus *Ulmus*, and have introduced the elm pathogens into a wide range of climatic and habitat types. Thirdly, the close physical contact between *O. ulmi* and *O. novo-ulmi* (and other *Ophiostoma* species) which can occur in the breeding galleries of the scolytid vectors, provides opportunities for genetic exchange and hybridization. Although any hybrids are rare and tend to be unfit, the process has apparently allowed *O. novo-ulmi* to acquire genes that control mating type, vegetative compatibility and possibly even toxin production (Brasier *et al.*, 1998).

ALDER *PHYTOPHTHORA* DISEASE

The alder *Phytophthora* is less well known, but is currently causing widespread killing of riparian and shelterbelt alders across Europe (Gibbs *et al.*, 2003). In the UK alone, it is estimated that more than 15% of riparian alders have been affected or killed by the disease since its discovery in 1993 (Webber *et al.*, 2004). Newly named as *Phytophthora alni*, the pathogen is not a uniform species but swarm of heteroploid hybrids between two exotics – *P. cambivora* and a species of *Phytophthora* close to *P. frageriae* (Brasier *et al.*, 1999). The most common hybrid type, which is the most pathogenic to alder, is known as *P. alni* ssp. *alni*, whereas the other hybrid types are collectively known as *P. alni* ssp. *uniformis* and ssp. *muliformis* (Brasier *et al.*, 2004a). Interestingly, neither *P. frageriae* nor *P. cambivora* is a pathogen of alder, but the hybrid *P. alni* is both highly aggressive and specific to alder.

The hybrid nature of the *P. alni* subspecies is evinced by instability in culture, zygotic abortion and variation in chromosome numbers. ITS (Internal transcribed spacer region of the rDNA) sequences and AFLP patterns of genomic DNA also indicate that the hybrids have only recently evolved and are still evolving. The circumstances of the hybridization remain obscure, but plant nurseries may have provided the ideal cradle for the origin of the new species. *Phytophthora* spp. are frequently found in nurseries; often, these include species previously geographically separated from each other. The mixing of *Phytophthora* spp. and plant species that may originate from all over the world, and the use of disease suppressive chemicals, could have encouraged the process of hybridization. Certainly there is evidence that *P. alni* is disseminated on alder plants that have become infected in the nursery; in Germany it has been found on the root stocks of alder in three out of four commercial nurseries that were tested (Jung *et al.*, 2003).

Once again, several features have probably contributed to the invasive behaviour of the alder *Phytophthora*. Long-distance international movement of the pathogens has probably occurred via the trade of infected, but symptom-free, plants. In addition, spores of the alder *Phytophthora* (zoozpores) are free-swimming, and therefore adapted to dispersal in water. Thus, once the hybrid pathogen is introduced into a river system, spread down river is probably assured and it is brought into direct contact with the susceptible alders (which are a dominant part of riparian habitats). The hybridization event has also allowed this *Phytophthora* to exploit a new host genus not previously susceptible to *Phytophthora*. Meanwhile, it continues to change and evolve. How the evolution will proceed is uncertain, as is the extent of the threat this disease poses to alder species outside Europe.

SUDDEN OAK DEATH

Apparently only recently established, *Phytopththora ramorum* is causing a disease known as sudden oak death in some mixed-hardwood forests in California and south western Oregon. *P. ramorum* has a broad host range; more than 60 species have been recorded. It has been found killing several tree species within the Fagaceae, but also causes leaf blight and shoot dieback in a highly diverse group of ornamentals, understorey shrubs and trees (Davidson *et al.*, 2003). In Europe *P. ramorum* has been found in plant nurseries, landscape plantings and, to a lesser extent, woodlands, and surveys show that it has been introduced into a number of European countries by movement of infected plants. The year 2004 also saw the accidental movement of infected stock from one nursery in California to many other states across the USA.

The disease cycle of *P. ramorum* is not straight forward. Certain hosts suffer only foliar or shoot infections, but the pathogen sporulates abundantly on the infected tissue. In contrast, the bleeding stem lesions which kill trees apparently generate few, if any, spores. The spore-producing foliar hosts, such as bay laurel (*Umbellularia california*) in California and rhododendron in Europe, therefore act as the platform from which the pathogen infects trees. It has also become clear that European and American populations of *P. ramorum* have molecular and behavioural differences, and also differ in mating type (Werres *et al.*, 2001; Brasier, 2003; Ivors *et al.*, 2004). These population differences point to separate introductions of *P. ramorum* into each continent from an unknown origin, with differential adaptation of the populations after introduction. The geographical origin of *P. ramorum* is still a matter of speculation, but it has been suggested that Yunnan in south-west China, Taiwan or the eastern Himalayas might be home to the pathogen (Brasier *et al.*, 2004b).

The damage *P. ramorum* has caused to some forest ecosystems in the USA over the last five or more years is considerable. Some forests in central coastal parts of California have lost up to 80% of susceptible tree species such as tanoak (*Lithocarpus densiflorus*) and native oaks (*Quercus agrifolia* and *Q. kellogii*) to this disease. The genetically distinct European population of *P. ramorum* has now been found in at least 12 countries in Europe; but most infected plants consist of ornamental nursery stock. However, laboratory tests have shown that many woodland and plantation grown trees in Europe could be susceptible to the pathogen and the first naturally infected trees were found in the UK and the Netherlands in 2003. The heaviest infections on trees and rhododendrons have been in south-west England, where the climate is very similar to that of the areas of south-western Oregon affected by sudden oak death. Mild, moist climates typical of these areas are probably essential for the dispersal and infection phases of *P. ramorum*.

P. ramorum has proved to be highly invasive in the USA. Apart from dissemination via infected plants, in infested areas it can be isolated from rainwater, streams and soil. It may have the potential to cause similar levels of damage in Europe. The likelihood of it happening will depend on a number of factors, including suitable climatic conditions in at risk ecosystems with susceptible foliar and tree hosts, the build-up of inoculum of *P. ramorum*, and the ability to spread and persist. However, it has already proved it has the ability to infect and kill trees in Europe. Furthermore, in the very habitats where *P. ramorum* has established and infected trees in the UK, another new but unrelated species of *Phytophthora* has been discovered. This new pathogen, soon to be formally named as *P. kernoviae* (Brasier *et al.*, 2005), infects similar hosts and has a similar epidemiology to *P. ramorum*. The discovery raises the possibility of hybridization between these two new pathogens or with other phytophthoras they come into contact with in their new environment. It also suggests that the circumstances that lead to the accidental introduction and establishment of one pest or pathogen, may also encourage multiple introductions. Hansen *et al.* (2005) pointed out that it is the combination of wide host range, diverse symptom expression and aerial dispersal that creates the diagnostic and disease management challenge for *P. ramorum*. The same challenge also applies to *P. kernoviae*.

CONCLUSIONS

Global movement via the plant trade, exposure to new environments and vectors, and opportunities for hybridization, mean that introduced pathogens can have a potential impact far beyond the initial disease outbreaks that they cause. Each pathogen introduction must be considered as an uncontrolled and open-ended experiment in evolution, and a gamble with the long-term stability of our forests and other natural ecosystems.

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