A methodology for assessing the risk posed by the deliberate and harmful use of plant pathogens in Europe

Emilie Latxague[1], Ivan Sache[2], Jean Pinon[3], Didier Andrivon[1], Marc Barbier[4] and Frédéric Suffert[1,2,*]

[1]*Institut National de la Recherche Agronomique (INRA), Agrocampus Rennes, UMR1099 BiO3P (Biologie des Organismes et des Populations appliquée à la Protection des Plantes), Domaine de la Motte, BP 35327, F-35653 Le Rheu (France)*
[2]*INRA, Agro Paris Tech, UMR1290 BIOGER-CPP (Biologie et Gestion des Risques en Agriculture – Champignons Pathogènes des Plantes), BP 01, F-78850 Thiverval-Grignon (France); e-mail: fsuffert@grignon.inra.fr*
[3]*INRA, Université Nancy 1, UMR1136 IAM (Interactions Arbres Microorganismes), F-54280 Champenoux (France)*
[4]*INRA, Agro Paris Tech, UMR1048 SADAPT (Systèmes Agraires de Développement: Activités, Produits, Territoires), PRAxis, 16 rue Claude Bernard, F-75231 Paris (France)*
**Corresponding author*

Deliberate and malevolent use of plant pathogens, i.e. agroterrorism *lato sensu* (anticrop bioterrorism and use of bioweapons against the agricultural sector), may represent a non-negligible threat for crops and forests in Europe. In order to assess this risk objectively, a methodology based on a critical review of existing Pest Risk Analysis schemes has been elaborated and is described in the present paper. In this methodology, three interdependent steps are suggested: (i) definition of an *a priori* list of potentially dangerous plant pathogens for Europe, (ii) detailed elaboration and analysis of theoretical scenarios of possible acts of agroterrorism, and (iii) elaboration and use of a risk assessment scheme adapted to agroterrorism.

Introduction

Plant pathogens are responsible for numerous diseases of economic and social significance in crops and forests (Agrios, 2005; Strange & Scott, 2005). Several of them are currently perceived as a threat to global food security and agricultural industries in both developing countries and advanced industrialized societies. Although contemporary disease outbreaks have natural causes or are the result of inadvertent introduction of pathogens through human activities, the risk of a deliberate and harmful human introduction of a plant pathogen cannot be excluded. Concerns about agroterrorism have been raised increasingly over the last decade (Breeze, 2004; Casagrande, 2000; Cupp *et al*., 2004; Elad, 2005; Madden & Wheelis, 2003; Nutter, 2004; Roger *et al*., 1999; Schaad *et al*., 2006; Suffert, 2002, 2003; Whitby, 2002). This new context for security research outlines the need for collective and collaborative expertise of biowarefare and agroterrorism threats. It is necessary to clearly and scientifically identify the nature of the threats and determine how these can be managed, in order to improve crop biosecurity. In doing so, existing frameworks and capabilities of pest risk assessment are being renewed and modified, with potential effects on practices of pest surveillance and alert.

Context and objectives of the study

In line with the diverse definitions of agroterrorism or bioterrorism currently – and sometimes implicitly – used in international conventions, as well as in discussions between scientists and stakeholders about the origin and nature of terrorist acts, we proposed to focus on any targeted and harmful use of plant pathogens. We defined agroterrorism *lato sensu* (anticrop bioterrorism and use of bioweapons against crops) as the intentional use (as well as the threat or simulation of use) of plant pathogens (fungi, bacteria, viruses) by any human individual or group in order to cause direct damage to crops or forests, or to indirectly affect the agricultural sector.

Aware of these threats, scientists involved in plant protection research are currently developing a new field of activities related to the assessment and improvement of crop biosecurity (Fletcher *et al*., 2006; Latxague *et al*., 2006; Madden & van den Bosch, 2002; Schaad *et al*., 2006; Suffert *et al*., 2005). Most studies propose theoretical and pragmatic responses to agroterrorism risks, while being conscious that these responses may themselves enhance the capacities of actors engaged in terrorism (Wulf *et al*., 2003). The consequences and risks of mobilizing scientific knowledge and activities in this field of research need to be carefully considered, not only because research facilities are vulnerable to attack, but also because they could constitute entry points for agroterrorism.

Within the framework of the European Concerted Action 'CropBioterror', we have proposed and developed a risk assessment methodology specifically adapted to agroterrorism. During this process, three interdependent stages have been defined and are presented in Fig. 1. This methodology is based on a critical review of the current uses and limits of the 'Assessment' part of the Pest Risk Analysis (PRA) scheme detailed in the IPPC (2004) Standards in the particular context of agroterrorism.

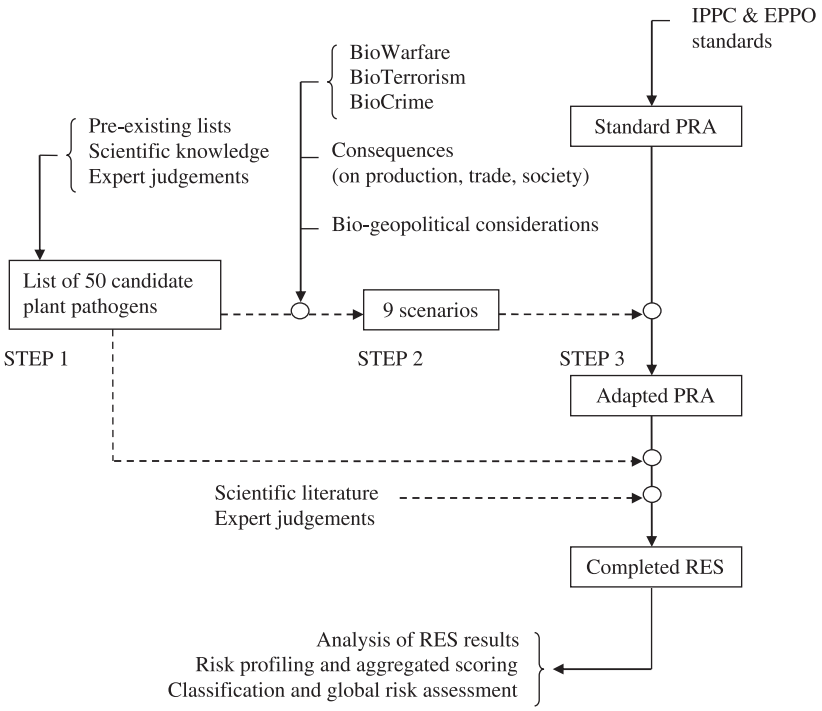

Fig. 1 Diagram of the methodology used for assessing the risk posed by the deliberate and harmful use of plant pathogens, incorporating the Risk Evaluation Scheme (RES).

Methodology

Stage 1 – List of candidate pathogens

During the first stage, plant pathogens that may pose a real threat to European agriculture and forestry were identified. Various international working groups and organizations (including the Biological and Toxin Weapons Convention, the Animal and Plant Health Inspection Service of the United States Department of Agriculture, the American Phytopathological Society, the European Union, the European and Mediterranean Plant Protection Organization, and the Centre for Non-proliferation Studies) have compiled lists of pathogens of quarantine or agroterrorism concern (Table 1). These lists were critically screened by the partners and experts of the European Concerted Action 'CropBioterror' and updated when necessary with relevant scientific information (bibliographical review of literature about crop biosecurity, evaluation of the importance of several target crops, expert judgments about the surveillance level of different regulated pathogens in Europe or about the specific risk-profiles of some of them, etc.). In addition, a specific evaluation was performed for forest pathogens (Pinon, 2006). At the end of the first stage, a list of 50 candidate pathogens was compiled, including fungi, bacteria and viruses, able to damage crops or forests after deliberate introduction. This list included exotic and quarantine pathogens that may induce emergent epidemics causing more or less damage in Europe (e.g. *Ceratocystis fagacearum*, *Erwinia amylovora*, *Mycosphaerella populorum*, *Pepino mosaic potexvirus*, *Pleospora papaveracea*, *Plum pox potyvirus*, *Phakopsora pachyrhizi*, *Ralstonia solanacearum*, *Synchytrium endobioticum*, *Tilletia indica*, *Xylella fastidiosa*), but also more common indigenous pathogens causing recurrent epidemics. These indigenous pathogens were selected because they presented particular risk-profiles such as: the production of mycotoxins (e.g. *Claviceps purpurea*, *Fusarium graminearum*, *Gibberella zeae*, *Penicillium expansum*) or the existence of exotic strains which could dominate or hybridize with local ones (e.g. *Leptosphaeria maculans*, *Phytophthora infestans*, *Puccinia triticina*). This list of 50 pathogens is not exhaustive or closed, but is a list of potential candidates that should be assessed. The names of these pathogens were delivered to the EU Commission, which is the official depositary of the final report of the Concerted Action 'CropBioterror'. However, Table 2 presents the nature of the 50 selected pathogens, the target crops, and possible consequences of their use. For further information, please contact the corresponding author. Nine key pathogens were then selected from the full list to elaborate realistic and specific scenarios of agroterrorist acts according to their risk-profiles (stage 2), and to validate the Risk Assessment Scheme (RES) (stage 3).

Stage 2 – Scenarios of agroterrorist acts

In the second stage, theoretical scenarios of possible agroterrorist acts were elaborated in order to highlight key features of potential attacks within Europe. During the development of these scenarios, three different types of actions were considered: Biowarfare (BW – international, state-sponsored terrorism or military action), Bioterrorism (BT – non-governmental act of

Table 1 Referenced lists of plant pathogens that could potentially be used in acts of agroterrorism in the world (available on the Internet in March 2007)

Organization	List	Fungi	Bacteria	Viruses
BTWC-SA	WP.124 by South Africa Plant pathogens important for the Biological and Toxin Weapons Convention (BTWC)[1]	13	6	1
BTWC-PR	*ad hoc* Group 56/1 Procedural Report[2]	4	3	1
USDA-APS	List of biological agents and procedures for notification[3]	4	5	1
USDA-APHIS	Agricultural Select Agent Program Select agent and toxin list[4]	3	5	0
European Union	EU Plant Health Directive 2000/29/CE[5]	19	3	34
EPPO	Lists of pests recommended for regulation in the EPPO region[6]			
	A1 List	38	11	23
	A2 List	20	22	19
CNS	'Select agent' list of pathogens and toxins[7]	18	11	3
Australia Group	List of plant pathogens for export control[8]	8	6	3
ISSG-IUCN	100 of the World's worst invasive alien species[9]	3	1	0
CBWinfo	Plant pathogens with biological weapons potential[10]	27	17	1

[1]Established by the ***ad hoc* Group of the Biological and Toxin Weapons Convention (BTWC)** (signed on 10 April 1972). The **Working Paper by South Africa** was presented during the 6th session, held in Geneva, on **3–21 March 1997** (BWC/AD HOC GROUP/WP.124). The list, entitled 'Plant pathogens important for the BWC', was drawn up at the 4th session of the *ad hoc* Group and was re-evaluated at the 6th session. The criteria were:
- agents known to have been developed, produced or used as weapons
- agents which have severe socio-economic and/or significant adverse human health impacts, due to their effect on staple crops.

Official website: Reference: http://www.opbw.org/
List: http://www.bradford.ac.uk/acad/sbtwc/ahg34wp/wp124.pdf

[2]Established by the ***ad hoc* Group of the Biological and Toxin Weapons Convention (BTWC)** (signed on 10 April 1972). The list belongs to the **Procedural Report of the 23rd session**, held in Geneva on **23 April–11 May 2001** (BWC/AD HOC GROUP 56/1). 'Each state party shall declare agents and toxins from the lists set out in Annex A, section I, in accordance with the format for declarations of facilities, activities and transfers referred to in Annex A, section IV'. The following criteria were used to develop the list of agents and toxins, and will be used again to review any modification proposed:
- potential of individual agents and toxins to be used as weapons
- scientific and technological developments that may affect the potential of individual agents or toxins to be used as weapons
- effects of potential inclusion or exclusion of an agent or toxin in the list on scientific and technical research and development.

Official website: http://www.opbw.org/
List: http://www.bradford.ac.uk/acad/sbtwc/ahg56/doc56-1.pdf

[3]Established by the **Animal and Plant Health Inspection Service (APHIS)** of the **United States Department of Agriculture (USDA)**. The list is displayed on the **American Phytopathological Society (APS)** website, together with a paper that presents APS' positions and recommendations on countering agricultural bioterrorism with crop biosecurity practices.
This list was prepared by USDA as part of the Agricultural Bioterrorism Protection Act of 2002: Listing of Biological Agents and Procedures for Notification, in consultation with APS. This law is designed to 'improve the ability of the United States to prevent, prepare for, and respond to bioterrorism and other public health emergencies that could threaten public health and safety or American agriculture'. In determining whether a select agent or toxin should be included on the list, the following criteria were considered:
- effect of an agent or toxin on animal or plant health, or on animal or plant products
- virulence of an agent or degree of toxicity of the toxin and the methods by which the agents or toxins are transferred to animals or plants
- availability and effectiveness of medicines and vaccines to treat and prevent any illness caused by an agent or toxin
- other criteria that the Secretary considers appropriate to protect animal or plant health, or animal or plant products.

It was published in the Federal Register of **12 August 2002**.
Official website: http://www.apsnet.org/
List: http://www.apsnet.org/members/ppb/RegulatoryAlerts/FEDREG8-12-02.pdf

[4]Established by the **Animal and Plant Health Inspection Service** of the United States Department of Agriculture. In accordance with the Agricultural Bioterrorism Protection Act of 2002, implementing regulations detailing the requirements for possession, use, and transfer for select agents and toxins, this list was published by Health and Human Services (HHS) and by USDA on **18 March 2005**. It specifies select agents and toxins.
Official website: http://www.aphis.usda.gov/
List: http://www.biosafety.msu.edu/selectagents/Select_Agent_List.pdf

[5]Established by the **European Union (EU)**. The Annexes of Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the European Community of organisms harmful to plants or plant products and against their spread within the Community contain a list of quarantine pests. Published in the Official Journal L169, on **10 July 2000**.

Official website: http://europa.eu/index_en.htm
List: http://www.boku.ac.at/IAM/pbiotech/eppl.pdf

[6]Established by the **European and Mediterranean Plant Protection Organization (EPPO)**, which is an intergovernmental organization responsible for cooperation in plant protection in the European and Mediterranean region. Under the International Plant Protection Convention (IPPC), EPPO is the regional plant protection organization (RPPO) for Europe. One of EPPO's aims is to inform its member countries about dangerous pests, thus helping them to prevent their entry or spread. The organization has therefore been given the task of identifying pests that may present a risk, and of making proposals on the phytosanitary measures that can be taken. The EPPO A1 and A2 Lists contain pests which have been evaluated by EPPO as presenting a risk to its member countries and which it recommends regulating as quarantine pests. A1 pests are absent from the EPPO region while A2 pests are locally present in the region. These lists are updated each year (lists approved in 2006 were used in the present study).
Official website: http://www.eppo.org/
List: http://archives.eppo.org/EPPOStandards/PM1_GENERAL/pm1-02(15)_A1A2_2006.pdf

[7]Established by the **Center for Non-proliferation Studies (CNS)**, at the Monterey Institute of International Studies. It is the largest non-governmental organization in the United States devoted exclusively to research and training on non-proliferation issues. It strives to combat the spread of weapons of mass destruction by training the next generation of non-proliferation specialists and disseminating timely information and analysis. Today, CNS has a full-time staff of more than 40 specialists and over 50 graduate student research assistants. The 'select agent' list of pathogens and toxins was published in **November 2002** and compiles the data given by eight other biological agent lists. Authors: Croddy E and Newhouse L.
Official website: http://cns.miis.edu/
List: http://cns.miis.edu/research/cbw/biosec/pdfs/agents.pdf

[8]Established by the **Australia Group**, published in **April 2005**. The Australia Group is an informal group with the aim of allowing exporting or transhipping countries to minimize the risk of assisting chemical and biological weapon (CBW) proliferation. Participants in the Australia Group do not undertake any legally binding obligations: the effectiveness of their cooperation depends solely on a shared commitment to CBW non-proliferation goals and the strength of their respective national measures. All states participating in the Australia Group are parties to the Chemical Weapons Convention and the Biological and Toxins Weapons Convention. This group has established a list of plant pathogens for export control.
Official website: http://www.australiagroup.net/
List: http://www.australiagroup.net/en/control_list/plants.htm

[9]Established by the **Invasive Species Specialist Group (ISSG)**, which is part of the **Species Survival Commission of the World Conservation Union (IUCN)**. The ISSG is a group of 146 scientific and policy experts on invasive species from 41 countries. It aims to reduce threats to natural ecosystems and the native species they contain by increasing awareness about invasive alien species, and defining ways to prevent, control or eradicate them. Species included in the list of '100 of the World's worst invasive alien species' were selected according to two criteria: their serious impact on biological diversity and/or human activities, and their illustration of important issues related to biological invasions. Only pathogens that are considered to be invasive are included in this list. Authors: Lowe S, Browne M, Boudjelas S and De Poorter M.
Official website: http://www.issg.org/
List: http://www.iucn.org/places/medoffice/invasive_species/docs/invasive_species_booklet.pdf

[10]Displayed on the **Chemical and Biological Weapons Info (CBWinfo)** website. CBWinfo is an independent initiative that tries to provide accurate and useful information on classes of weapons of mass destruction for emergency and security personnel for training and background information as well as to help the general public better understand the nature of these weapons. This list is largely based on that of the Australia Group with some additional agents that are considered to present a risk by the North Atlantic Treaty Organization (NATO). Last updated: **12 January 2002**.
Official website: http://www.cbwinfo.com/
List: http://www.cbwinfo.com/Biological/PlantPath.html

aggression by individuals or groups) and Biocrime (BC – criminal behaviour by individuals or groups, with economic gain for perpetrators). The deliberate use of any of the 50 listed pathogens could have negative consequences on production or trade as well as having social impacts. Five main types of consequences were identified and are shown in Table 3. Nine scenarios were then elaborated, each one being associated with a key pathogen chosen from the compiled list. All three types of actions and several combinations of their consequences are covered by the nine scenarios. In the present paper, only a brief description of the nine scenarios of agroterrorist acts is presented (Table 4), but in our project each scenario was described precisely (four- to six-page text containing a prospective 'story') using current geopolitical knowledge as well as published information on the biology of the pathogen, and was fully documented with bibliographical references to scientific or grey literature, including existing works on agroterrorism (Madden & Wheelis, 2003; Paterson, 2006; Roger *et al*., 1999; Schaad *et al*., 2006; Wheelis *et al*., 2002; Whitby, 2002). Each scenario was divided into three sections: Synopsis, Justification and Feasibility. The analysis of these nine scenarios allowed us to formulate conclusions about agroterrorism: possibilities of malevolent use of plant pathogens (quarantine and exotic pathogens, as well as indigenous), choice of the pathogen according to the expected impact (production of mycotoxins, potential impact on trade because the pathogen is regulated), scientific expertise and access to the information (easily available via the Internet or only in scientific publications), need to assess the risk (important target crop or minor production), etc. These scenarios also allowed us to identify several common characteristics of potential agroterrorist attacks in Europe. Conclusions from the detailed analysis of the nine scenarios will be presented in another paper (in preparation).

Stage 3 – Risk Assessment Scheme

A risk assessment scheme was elaborated as the third stage of the programme. Although Pest Risk Analysis (PRA) schemes

Table 2 List of 50 candidate plant pathogens that could potentially be used in acts of agroterrorism in Europe

			Consequences[2]		
Code[1]	Nature	Host plant/target crop	PROD	TRAD	SOC
P01	bacterium	citrus	+	+	+
P02	fungus	fir, spruce, pine, larch, tsuga	+	+	+
P03	phytoplasm	grapevine	+	+	+
P04	fungus	grapevine	+	+	+
P05	fungus	oak	+	+	+
P06	virus	peach	+	+	+
P07	fungus	pine	+	+	+
P08	fungus	pine	+	+	+
P09	fungus	pine	+	+	+
P10	fungus	poplar	+	+	+
P11	bacterium	potato	+	+	+
P12	bacterium	potato	+	+	+
P13	fungus	rice, cereals	+	+	+
P14	fungus	spruce	+	+	+
P15	bacterium	apple	+	+	0
P16	bacterium	citrus	+	+	0
P17	bacterium	melon	+	+	0
P18	fungus	oilseed rape	+	+	0
P19	bacterium	oilseed rape	+	+	0
P20	oomycete	pea	+	+	0
P21	fungus	pea	+	+	0
P22	fungus	potato	+	+	0
P23	virus	tomato	+	+	0
P24	virus	tomato	+	+	0
P25	fungus	larch, douglas fir	+	0	+
P26	fungus	poppy	+	0	+
P27	oomycete	potato	+	0	+
P28	fungus	rice	+	0	+
P29	fungus	rice	+	0	+
P30	fungus	maize	+	0	0
P31	bacterium	onion	+	0	0
P32	fungus	soybean	+	0	0
P33	virus	tomato, tobacco	+	0	0
P34	fungus	wheat	+	0	0
P35	fungus	apple	0	+	+
P36	fungus	maize, soybean, peanut	0	+	+
P37	fungus	maize, wheat	0	+	+
P38	fungus	maize, wheat, barley	0	+	+
P39	fungus	maize, wheat, barley	0	+	+
P40	oomycete	oak	0	+	+
P41	fungus	wheat	0	+	+
P42	fungus	date	0	+	0
P43	virus	potato	0	+	0
P44	virus	potato, tomato	0	+	0
P45	fungus	wheat	0	+	0
P46	fungus	wheat	0	+	0
P47	fungus	wheat	0	+	0
P48	fungus	wheat, barley	0	+	0
P49	fungus	larch	0	0	+
P50	fungus	maize	0	0	+

[1]Names of plant pathogens do not appear in the present list for biosecurity reasons. The complete list was delivered to the European Commission, which is the official depositary of the final report of the Concerted Action 'CropBioterror'. For further information, please contact the corresponding author.
[2]PRO = impacts on production; TRA = trade affected by regulatory measures or embargoes; SOC = impacts on animal and human health, patrimonial and environmental losses, panic and psychological effects on civilian populations; + = yes, 0 = no.

Table 3 Five potential consequences of acts of agroterrorism on production (PRO), trade (TRA), and society (SOC)

1.	Impacts on production (PRO)
2.	Trade affected by regulatory measures or embargoes (TRA)
3.	Impacts on animal and human health (SOC)
4.	Patrimonial and environmental losses (SOC)
5.	Panic and psychological effects on civilian populations (SOC)

are international standards used to assess the risk of introduction and establishment of a pathogen within a region (IPPC, 2004; OEPP/EPPO, 2006; Schrader & Unger, 2003), they are not directly suitable for the assessment of agroterrorism risks. Major items were added to the standard PRA scheme to adapt the methodology of risk assessment to the specificity of agroterrorism. Firstly, as plant pathogens can be a threat for several reasons, no fundamental distinction was made between regulated (quarantine) and non regulated pests. Secondly, the importance (acreage and uses) of the target crops needed to be taken into account; for example, attacks on wheat (an annual crop, largely used in the food industry) would not have the same consequences than attacks on poplar trees (perennial species, used as an industrial product). In addition, because agroterrorism consists of a deliberate action, availability and ease of production of the pathogens were considered in the risk assessment. Additionally, the analysis of the nine scenarios allowed us to identify critical points where standard PRA schemes should be amended: accessibility of information, inclusion of non quarantine pathogens, social importance of the target crop, characteristics of a deliberate action, importance of several types of consequences, etc. From those considerations we propose an adapted scheme, called the Risk Evaluation Scheme (RES) (Table 5), which includes the following five sections:

1 Importance of the target crop,
2 Ease of use of the pathogen,
3 Epidemic potential of the pathogen,
4 Obstacles to swift and effective response, and
5 Potential global or regional consequences.

This RES was applied to selected pathogens from the list by a single non-expert risk-assessor. Each item of the completed RES was scientifically documented and assessed according to a selection of 10 (if possible) relevant scientific publications on the organism. An uncertainty grading was given to evaluate its accuracy. Each assessment may be validated by experts afterwards. The results of the completed RES was analysed to determine and categorize different risk profiles. Their analysis will be the subject of another paper including a critical assessment of the present methodology (in preparation).

Discussion

The current RES considered the full diversity of potential agroterrorist acts, even though some events are less likely to occur than others. The nine scenarios helped the risk-assessor to produce a generic risk assessment that considered several types of events, although it is possible that the risk assessment for a given pathogen may have been overly dependent on one or several corresponding scenarios. We assume that such a dependency is not a bias but rather is a property of our methodological framework, and that it is appropriate because terrorist threats *lato sensu* (Biowarfare, Bioterrorism and Biocrime) are specific. Consequently, an improvement of the current methodology would be needed in order to understand the dependency of the RES (stage 3) on the nine scenarios (stage 2), particularly regarding any threats that may not have been discussed in the scenarios. Other intrinsic limitations still have to be taken into account. Firstly, transdisciplinarity is required in order to manage the hybrid nature of agroterrorist threats (Barbier, 2006), because any given threat is formed of risks theorized with different sources of knowledge: on one side, knowledge about the potential harmful effects of a pathosystem on a cropping system or an agri-food chain; and on the other side, knowledge about the socio-economic and political consequences of a purposefully aggressive human action. Secondly, experts and authorities need to clarify how to use the information generated in the current programme in order to avoid misleading the public about the risks of

Table 4 Description of the nine types of agroterrorism scenarios

Biowarfare	
BW1	Attack by a country on the agricultural sector of another country. The aim of the attacker is to block commercial imports of the targeted products and prevent their entry into its national market or to enhance its own exports.
BW2	Attack by a country on the agricultural production of another country, in order to weaken the targeted country by reducing its domestic food supplies. This action could be undertaken before a military intervention or replace it.
BW3	Use of biological agents by a country to eradicate illicit crops in another country, such as drug cultivation.
Bioterrorism	
BT1	Terrorist attack targeting food crops. The use of the agent may have negative impacts on human or animal health.
BT2	Attack against planted trees or crops by ecowarriors who want to carry out a radical ecological action.
BT3	Terrorist attack aimed to damage a crop or a tree species that belongs to the patrimony of a country or a group of countries.
Biocrime	
BC1	Attack by activists or farmers groups against the production of a competing country.
BC2	Isolated attack by an individual working in the crop protection field, looking for revenge upon a colleague or an institution.
BC3	Deliberate use of a plant pathogen by a private company. The aim would be to render farmers dependant on specific cultivars or plant protection products.

Table 5 Outline of the Risk Evaluation Scheme (RES)

A. INITIATING THE PROCESS

A.1. Request.

A.2. Brief description of the pathogen.

A.3. Scientific references.

A.3.1. Occurrence in existing referenced lists (Table 1).

A.3.2. List of 10 scientific publications about the pathosystem (used to fill the risk evaluation).

A.3.3. Previous Pest Risk Analyses (PRA) established for regulation of the pathogen (wherever in the world).

A.3.4. Scientific experts (to be potentially consulted for additional information or further updates of this risk evaluation).

B. THREAT IDENTIFICATION

B.1. The pathogen.

B.1.1. Names (scientific and English; specify if several names exist for the same organism).

B.1.2. Nature (fungus, oomycete, bacterium, virus, phytoplasm).

B.1.3. Target crop(s) (name).

B.1.4. Life cycle of the pathogen (briefly describe the life cycle of the pathogen).

B.1.5. Potential harmfulness according to partners and experts of the Concerted Action 'CropBioterror' (not a threat = 0; very dangerous = 3).

B.2. Possible scenario(s) (state the most likely, and if needed, the other ones that could be linked with this organism: BW1, BW2, BW3, BT1, BT2, BT3, BC1, BC2, BC3; see Table 4)

B.3. Potential consequences of the deliberate use of the organism (several consequences are possible: PRO, TRA, SOC; see Table 3).

C. RISK EVALUATION

C1. EVALUATION OF THE IMPORTANCE OF THE TARGET CROP (scoring: not important = 0; very important = 10)

C.1. Importance of the target crop.

C.1.1. Target crop of the pathogen (name). Type of target (crop or tree species, annual or perennial).

C.1.2. Importance of the crop in Europe. Main uses for the crop (specify and provide figures if available). Acreage and production in Europe.

C2. EVALUATION OF THE EASE OF USE OF THE PATHOGEN (scoring: very difficult = 0; very easy =10)

C.2. Possibility of intentional use.

C.2.1. Accessibility of scientific knowledge about the pathogen (date). Number of Google references containing the entire scientific name of the pathogen (see http://www.google.com/). Number of CAB abstracts containing the entire scientific name of the pathogen (see http://portal.isiknowledge.com/portal.cgi).

C.2.2. Previous attempts to use this pathogen in a deliberate way (yes/no, why, how).

C.2.3. Ease of deliberate use.

C.2.3.1. Availability of the pathogen in collections (yes/no, where and restrictions). Can be collected in already contaminated areas (yes/no, where and conditions of collection). Major laboratories working with the pathogen (estimation of their number: none = 0; many = 3).

C.2.3.2. Cultivation. Ease of cultivation (not easy = 0; very easy = 3; specify technical constraints). Knowledge about growth conditions available (yes/no).

C.2.3.3. Inoculum production. Which part of the organism can be an inoculum? (specify). Time required for inoculum production (few hours =1; weeks = 3). Quantity of inoculum produced (little = 1; much = 3).

C.2.3.4. Stability. Duration of inoculum conservation (hours = 1; years = 3). Stability of inoculum (unstable = 0; very stable = 3).

C.2.3.5. Inoculation. Quantity of inoculum needed (little = 1; much = 3). Ease of transportation (difficult = 1; easy =3). Ease of inoculation (difficult = 1; easy = 3).

C3. EVALUATION OF THE EPIDEMIC POTENTIAL OF THE RATHOGEN (scoring: low = 0; high = 10)

C.3. Epidemic potential.

C.3.1. Establishment.

C.3.1.2. Distribution of the major hosts in Europe (localized = 1; widely distributed = 3). Possible minor hosts of the pathogen (specify). Identification of the main endangered area (if possible, according to the importance of the crop).

C.3.1.1. The pathogen. Area of origin and brief history of spread (specify). Current world distribution and presence in Europe (specify). Is European climate suitable for the pathogen? (not suitable = 0; very suitable = 3). Adaptability of the pathogen (records of special forms or strains, changes in behaviour, etc.).

C.3.2. Development. Possible number of infection cycles per growing season (few = 1; many = 3). Rate of development, typical timing of the life cycle (specify). Human practices that modify the development (which, how do they affect development?).

C.3.3. Dissemination and dispersal. Natural means of dispersal (specify). Natural range of dissemination (small = 1; large = 3). Is there any host known to be invasive in Europe? (yes/no). Cropping practices that modify dispersal (which, how do they affect dispersal?).

C.3.4. Conservation and survival. Conservation media (soil, air, water). Survival forms (specify). Conditions and duration of survival (specify). Human practices that can modify survival (which, how do they affect survival?).

C4. EVALUATION OF THE OBSTACLES TO SWIFT AND EFFECTIVE RESPONSE (scoring: many = 0; none = 10)

C.4. Possibilities of action against the pathogen.

C.4.1. Detection. Methods of detection (specify). Ease of identification of the pathogen, possibility of confusion with other species (no doubts = 0; confusable = 3). Programme of detection within the EU (yes/no; if yes, specify). Expertise of the persons in charge of the identification and expert judgments (none = 0; many = 3).

C.4.2. Control measures. Efficacy and cost of control measures (specify). Eradication programmes within the EU (yes/no; if yes, specify). Records of successful or ongoing eradications or of efficient measures from other parts of the world (yes/no; if yes, specify).

Table 5 *Continued*

C5. EVALUATION OF THE POTENTIAL GLOBAL OR REGIONAL CONSEQUENCES (scoring: low = 0; high = 10)
C.5. Impact and consequences (including results of existing PRAs).
C.5.1. Impact on production.
C.5.1.1. Direct economic losses. Damage on the whole plant, parts of plant or plant products (specify).Type of plant damage for the growers (e.g. technological damage, growth reduction of host plant, quantitative damage, qualitative damage). Production losses associated with the pathogen (indicate current economic thresholds, if possible). Evaluation of direct economic losses (few = 1; many = 3).
C.5.1.2. Indirect economic losses. Market losses (none = 0; many =3). Impact of control measures used against the pathogen on the control of other pests (in particular the interaction with existing biological or integrated control measures) (no impact = 0; large impact =3). Evaluation of losses due to crop downgrading or costs of compensations eventually paid to growers (specify and give an evaluation).
C.5.1.3. Gain and profit for the industry or for producers of substitutes. Gain and profit for the agro-industry (plant protection products) (none = 0; high = 3). Gain and profit for substitution industry (none = 0; high = 3).
C.5.2. Impact on trade.
C.5.2.1. Economic and strategic losses for the trade of the country concerned and global market disturbance (none = 0; very important = 3). Estimated effect of the presence of the pest on exported commodities on countries to which they can no longer be exported, conditions under which they can be exported, market value (explain and give an evaluation). Control costs. If possible compare the costs deriving from the establishment of the pathogen and the estimated costs of exclusion (specify and give an evaluation).
C.5.2.2. Gain due to protectionist measures / closure of markets (none = 0; very important = 3).
C.5.3. Social and cultural impact.
C.5.3.2. Potential damage on populations (human and/or cattle). Potential damage on human populations due to the lack of food supply (none = 0; very important = 3). Potential damage on human health: production of mycotoxins (yes/no, which ones and quantity); if yes: effects on human health and/or on cattle health (specify); capacity of detection and quantification of mycotoxins (low = 1; high = 3); mycotoxin maximum levels allowed in food/feed in Europe (specify).
C.5.3.1. Environmental losses. Losses of genetic resources (none = 0; high = 3).
C.5.3.2. Patrimonial losses (none = 0; high = 3).
C.5.3.3. Psychological and socio-political impact. Psychological effect on populations (none = 0; high = 3). Specific impact on growers (none = 0; high = 3).
C6. OVERALL ASSESSMENT OF THE QUANTITY AND AVAILABILITY OF INFORMATION FOR THE RISK EVALUATION (scoring: none = 0; a lot = 10)

agroterrorism and the nature of this kind of assessment as has unfortunately occurred in recent years with food scares (Leiss, 1995).

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Méthodologie d'analyse du risque lié à l'utilisation volontaire et malveillante d'agents phytopathogènes en Europe

L'utilisation volontaire et malveillante d'agents phytopathogènes, i.e. agroterrorisme *lato sensu* (bioterrorisme anti-cultures et emploi d'armes biologiques contre le secteur agricole), représente une menace contre les cultures et les forêts européennes qu'il ne faut pas négliger. Afin d'évaluer ce risque de manière objective, une méthodologie s'appuyant sur une analyse critique des schémas d'Analyse de Risques Phytosanitaires existants a été élaborée et est décrite dans le présent article. Dans cette méthodologie, trois étapes interdépendantes sont proposées : i) élaboration d'une liste *a priori* constituée d'agents phytopathogènes potentiellement dangereux pour l'Europe, ii) rédaction détaillée et analyse de scénarios théoriques d'actes d'agroterrorisme potentiels, iii) conception et application d'un schéma d'analyse de risque adapté à l'agroterrorisme.

Методология оценки риска преднамеренного и злоумышленного использования растительных патогенов в Европе

Преднамеренное и злоумышленное использование растительных патогенов, так называемый «биотерроризм» *lato sensu* (биотерроризм, направленный на определенную сельскохозяйственную культуру, а также использование биологического оружия против сельскохозяйственного сектора экономики) может представлять собой немалую угрозу для сельскохозяйственных культур и лесов в Европе. Для объективной оценки такого риска была разработана описанная в данной работе методология, основывающаяся на критическом рассмотрении имеющихся схем Анализа Фитосанитарного Риска (АФР). В этой методологии предлагается выполнение трех независимых шагов: i) априорное определение перечня потенциально опасных патогенов растений в Европе, ii) детальная разработка и анализ теоретических сценариев возможных актов агротерроризма, iii) разработка и использование схемы оценки риска, адаптированной к агротерроризму.

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