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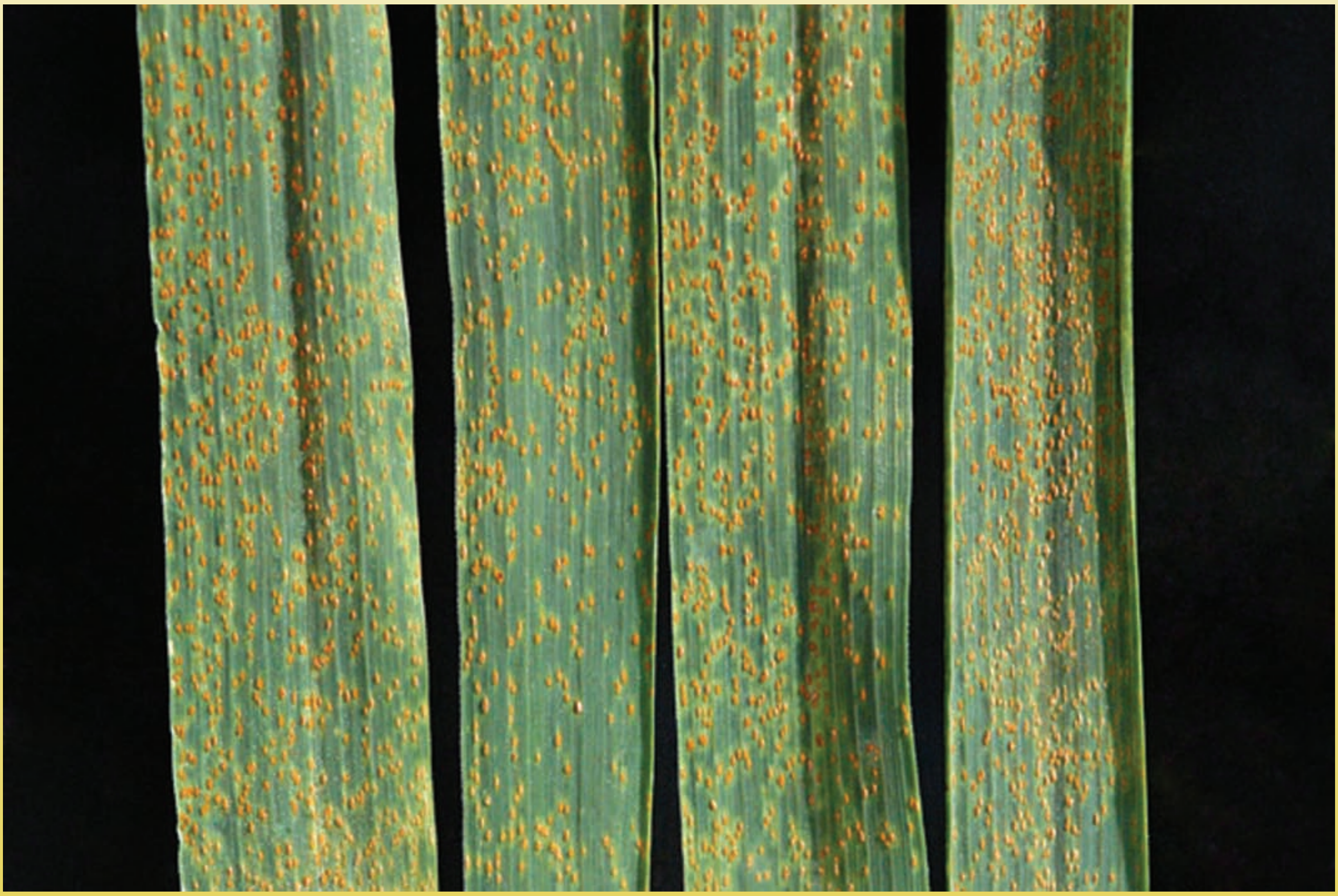
Risks to plant health: European Union priorities for tackling emerging plant pests and diseases



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building science into EU policy

EASAC

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Its mission reflects the view of academies that science is central to many aspects of modern life and that an appreciation of the scientific dimension is a pre-requisite to wise policy-making. This view already underpins the work of many academies at national level. With the growing importance of the European Union as an arena for policy, academies recognise that the scope of their advisory functions needs to extend beyond the national to cover also the European level. Here it is often the case that a trans-European grouping can be more effective than a body from a single country. The academies of Europe have therefore formed EASAC so that they can speak with a common voice with the goal of building science into policy at EU level.

Through EASAC, the academies work together to provide independent, expert, evidence-based advice about the scientific aspects of public policy to those who make or influence policy within the European institutions. Drawing on the memberships and networks of the academies, EASAC accesses the best of European science in carrying out its work. Its views are vigorously independent of commercial or political bias, and it is open and transparent in its processes. EASAC aims to deliver advice that is comprehensible, relevant and timely.

EASAC covers all scientific and technical disciplines, and its experts are drawn from all the countries of the European Union. It is funded by the member academies and by contracts with interested bodies. The expert members of EASAC's working groups give their time free of charge. EASAC has no commercial or business sponsors.

EASAC's activities include substantive studies of the scientific aspects of policy issues, reviews and advice about specific policy documents, workshops aimed at identifying current scientific thinking about major policy issues or at briefing policy-makers, and short, timely statements on topical subjects.

The EASAC Council has 28 individual members – highly experienced scientists nominated one each by the national science academies of EU Member States, by the Academia Europaea and by ALLEA. The national science academies of Norway and Switzerland are also represented. The Council is supported by a professional Secretariat based at the Leopoldina, the German National Academy of Sciences, in Halle (Saale) and by a Brussels Office at the Royal Academies for Science and the Arts of Belgium. The Council agrees the initiation of projects, appoints members of working groups, reviews drafts and approves reports for publication.

To find out more about EASAC, visit the website – www.easac.eu – or contact the EASAC Secretariat at secretariat@easac.eu

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Foreword

Increasing political and societal awareness about food and nutrition security and their interdependence with other policy areas, in particular those relating to the environment and economic competitiveness, brings new opportunities and challenges for the sustainable intensification of agriculture. Science-based innovation is allowing us to produce more food, to reduce loss and wastage, and to manage our environment better[1]. But there is much still to do to ensure food security and preserve ecosystem resources. This report from the European Academies Science Advisory Council (EASAC) draws attention to the importance of tackling plant pests and diseases, an objective that is currently being addressed by the European Commission's reform of the Community Plant Health Regime, restricting the importation and movement of plants and plant products. These matters are of importance, not only for agriculture but also for horticulture and forest crops as well as for plants in their natural habitats.

The proposed new European Commission Regulation intends to introduce better surveillance and early eradication of harmful organisms to plants, and is an important step in upgrading and standardising the present practices across the European Union and in reaffirming the role for science in support of risk assessment. However, science and technology have much wider potential in their applications to the promotion of plant health and the defence against current and new threats. In particular, this report describes how advances in research can inspire new thinking on procedures for pest control and on breeding improved plant varieties with resistance to biotic stresses. Our conclusion is that the technical proposals in the European Commission's Regulation must be set into context and accompanied by action across a much broader front to embed innovation in agriculture, horticulture and forestry. In addition to the necessary increased support required for surveillance, training, research and its translation to practice, there must be renewed commitment to addressing those policy disconnects that currently act to deter innovation.

The report takes into account the evidence marshalled and lessons learnt in previous EASAC work[2] on agriculture and on human infectious diseases where there are some related issues for linking surveillance, investigation and control. Our recommendations are addressed to policy-makers in the European Union institutions and at Member State level. We emphasise the global importance of the issues for plant health and will continue to catalyse analysis and reflection among our academy colleagues worldwide. The protection of plant health is a shared responsibility and it is vitally important to raise public awareness of the issues. As we noted in our earlier report, 'Planting the future', EASAC will continue to encourage engagement with the community-at-large to stimulate debate and inform expectations so as to facilitate the exchange and wise application of knowledge.

The report has been prepared by consultation with a group of experts, nominated by our member academies. I thank them and their chairman, Professor Volker ter Meulen, and our independent reviewers for their assistance in assuring the quality of the report. I also thank my colleagues on Council and the Biosciences Steering Panel for their guidance in designing the project and their continuing assistance to deliver our messages.

Particular thanks go to my immediate predecessor as EASAC President, Professor Sir Brian Heap, who has inspired and advocated much of EASAC's recent work in the area of plant sciences.

We welcome discussion on any of the points raised in this report or on matters that might be studied in future work.

Professor Jos W.M. van der Meer
EASAC President

[1] This has been discussed in detail, for example at a recent symposium to accompany the 2013 World Food Prize: The Next Borlaug Century: Biotechnology, Sustainability and Climate Volatility; see http://www.worldfoodprize.org/index.cfm?nodeID=51991&audienceID=1

[2] (1) 'Planting the future: opportunities and challenges for using crop genetic improvement technologies for sustainable agriculture', 2013; (2) 'Plant genetic resources for food and agriculture: roles and research priorities in the European Union', 2011; (3) A series of projects on human infectious diseases was summarised in 'European public health and innovation policy for infectious disease: the view from EASAC', 2011. All publications are available on http://www.easac.eu.

Summary

The introduction and spread of plant pests and diseases among food crops and other plant species, particularly in forestry and horticulture, has significant consequences globally for farmers, the seed industry, policy-makers and the general public. The recent initiative by the European Commission to upgrade certain protective measures against plant pests is important in reinforcing technical aspects of risk analysis, quarantine and other controls. It also provides the opportunity to raise awareness of the need to tackle the wider issues associated with the threat from emerging plant pests and diseases to crops and forests and to the other ecosystem services provided by the environment.

In this report, the European Academies Science Advisory Council (EASAC) aims to do the following:

- clarify what is needed to achieve European Union (EU) goals in the analysis and management of plant health risk;
- highlight where science and innovation can contribute to improved surveillance, pest and pathogen characterisation, and integrated control options for sustaining plant health;
- evaluate where policy disconnects need to be resolved and where flexible, evidence-based, proportionate regulation must be ready to respond to future scientific advances and environmental change;
- identify gaps in knowledge and skills that need to be filled.

This report draws on previous EASAC analysis of related issues for plant sciences and breeding and for improving preparedness for and responsiveness to human infectious disease, and on published work by other advisory groups and guidance from EASAC academy-nominated experts. The issues addressed are relevant for agriculture, horticulture and forest crops as well as for plants in their natural habitats.

Recent evidence confirms that trans-boundary pests and diseases are of increasing importance for crop plant and ecosystem health and that climate change is having an impact. Previous regulation in the EU, governed by the European Community Plant Health Regime, has been only partly effective. From the perspective of EASAC, the new proposals from the European Commission to improve contingency planning and governance, and to simplify and strengthen regulation for plant health, must be accompanied by policy development and strategic action across a broad front to coordinate research and the collection and sharing of knowledge for improved surveillance and innovation.

EASAC recommendations cover the following priorities.

Surveillance systems

- Improving monitoring of pathogens and pests, to collect standardised and comprehensive data, with establishment of early warning systems.
- Committing to long-term data recording and better linkage between databases, including those for genetic characterisation, with faster exchange and use of epidemiological and other information between Member States and other regions.
- Using new forms of monitoring, including the social media.
- Extending surveillance outside of managed agricultural environments to natural habitats.
- Continuing to consider issues for bioterrorism.
- Ensuring that relevant work in universities and public research institutes is appropriately funded and coordinated with the activities of the plant health authorities.

Research and training

- Putting in place the necessary scientific infrastructure and networks to support surveillance, regulation and innovation.
- Ensuring that the scope of Horizon 2020 takes account of the detailed recommendations for the fundamental and applied research agenda compiled by the scientific community to address emerging risks within the broader context of understanding plant health. The recommended scope includes pest and disease diagnosis; biology, ecology and epidemiology of plant pests and pathogens and their relationships with hosts and vectors; plant pest and disease resistance; biological and cultural strategies for sustainable pest and disease management; and evaluation of how healthy plants live in association with microbes that provide direct or indirect benefit.
- Supporting this multi-disciplinary research strategy by reducing fragmentation in research capacity and priority-setting across Member States to sustain critical mass. For example, the ERA-NET initiative EUPHRESCO should be continued and extended.
- Increasing use of research and surveillance data in modelling, prediction and extrapolation, including application in coupled crop disease–weather interaction models.

- Attending to current and impending skill shortages in critical disciplines, including plant pathology and taxonomy, and creating better networking between disciplines and sectors.

- Ensuring the research issues for plant health receive appropriate attention within current European Commission initiatives, for example the Joint Programming Initiative on Agriculture, Food Security and Climate Change and the European Innovation Partnership on Agricultural Productivity and Sustainability.

Innovation

- Assigning higher priority to better use of research advances in support of innovation and the translation of knowledge from research centres to practical applications in support of plant health.

- Developing new, durable control approaches to overcome current limitations of pesticides and responding to challenges introduced by EU pesticide product legislation that reduces the number of approved chemical control options.

- Making most of the scientific opportunities for breeding improved plants, durably resistant to biotic stresses. Genetic improvement can be accomplished by more precise breeding techniques (for example, marker-assisted selection), by genetic modification to introduce desirable traits and by other, newer, crop genetic improvement technologies. To deliver these innovations, it is vital that the EU regulatory framework for approving crops developed using genetic improvement technologies is reformed to be proportionate and to focus objectively on the scientific evidence for benefit–risk for the plant trait.

- Implementing coordinated policy for regulation and innovation, encompassing broader thinking on healthy plants and considering options for building strategic linkages across plant–animal–human health ('One Health').

In conclusion, scientific advance is leading to rapid developments in diagnostic technologies, surveillance and communication methodologies, and to increased understanding of the current and emerging threats to plant health, and of the means to counter those threats. The issues to be faced in protecting and promoting plant health are scientific, technological and regulatory but they cannot be tackled successfully without also raising political and public awareness of the importance of the issues and the need to prepare for future challenges. This EASAC report is addressed to the EU institutions, to the Member States and to those responsible for developing regional strategies, to help raise visibility of the global importance of plant health and resilience for sustainable agriculture, food security and environmental protection.

1 Introduction

1.1 Emerging problems

Plant health is of global importance for sustainable agriculture, food security and environmental protection. The introduction and spread of plant pests and diseases among food crops and other socio-economically important plant species, particularly in forestry and horticulture, can have very significant consequences—for farmers, the seed industry, policy-makers and the general public. The European Commission has recently published its proposal (European Commission, 2013) to upgrade certain protective measures against plant pests. This is an important initiative to reinforce technical aspects of quarantine and other controls and it also helps to raise awareness of the wider issues associated with the threat of emerging plant pests and diseases to crops and forests and to the wider range of ecosystem services provided by the environment (EASAC, 2009a) .

EASAC is publishing the present report to contribute to efforts to achieve higher visibility for the promotion of plant health and is doing so now to build on the momentum created by the European Commission's initiative. We address our recommendations to policy-makers at the EU level – in the European Commission, European Parliament and Council of Ministers – and in the Member States, where complementary action will be necessary. As these issues are of relevance worldwide, EASAC will continue to stimulate discussion through the global academy networks.

Our intention, in initiating this project, was to take a scientific view of what is now possible:

(1) To clarify what additional infrastructure and actions are needed to achieve European goals in risk analysis and risk management.

(2) To highlight what else must be done to deliver innovation and sustain plant health alongside the European Commission's specified proposals for improved surveillance and quarantine.

(3) To show how science can inform policy options so that the EU will be able to respond to future scientific advances and environmental changes.

(4) To determine where good practice can be shared across agriculture, horticulture and forestry, and to identify gaps in knowledge and skills that need to be filled.

In this report, we describe how the specific actions proposed by the European Commission to simplify and strengthen the technical framework to manage the entry, establishment and spread of harmful organisms in the EU must be seen as part of a broader strategy to ensure effective protection against current and emerging plant pests and diseases. The proposed European Commission Regulation to upgrade the existing regimen must have sufficient flexibility to cope with the increasing threats to plant health from international trade, climate change and other growing challenges. Effective implementation of the Regulation will need strengthened scientific support. Furthermore, there is much greater potential to address the problems by using science and technology in additional ways to be described in the following chapters. Taking this more comprehensive approach will only be successful, however, if there is greater coherence in policy objectives in translating the advances in science and technology into the required practical applications. In particular, more attention must now be given to mitigating the detrimental consequences of the currently restrictive policies on pesticides and on evaluating risks in agricultural biotechnology. The current policy framework is not compatible with maximising the opportunities to tackle risks to plant health, and it is vitally important to raise political and public awareness of these concerns.

Accurate information on the extent of losses from pests and diseases is often not available, but estimates of 30–40% loss in developing countries annually from 'field-to-fork' are common (Royal Society, 2009; Flood, 2010) and may be even higher when post-harvest loss is taken fully into account. The EU Member States have monitoring and management mechanisms to mitigate the consequences of harmful effects on crop plants and forests, food reserves that limit the consequences, research capacity and technical support services to manage plant health, and warning systems enabling application of control measures. However, there is still much to be done in the EU to improve systems, to prepare for future threats, and to contribute to regional and global strategies to improve plant health and resilience. This requires prioritisation, to use the scientific evidence to clarify prospective cost–benefits for particular approaches to ascertain what is possible and to inform strategic goals and legislative developments.

Emerging problems in the EU can be caused by the spread of existing threats as well as by the appearance of new threats. Recent analysis indicates that trans-boundary pests and diseases are of increasing global and regional importance for crop plant and ecosystem health (see, for example, Fisher et al., 2012, which focuses on fungal pathogens[3]). The challenges to plant health come not just from fungi, bacteria and viruses and their vectors, but also from invertebrate pests, particularly insects and nematodes. To be successful, the causative agent must challenge a host plant at a stage when it is susceptible and at a time when environmental conditions are favourable to the causative agent. Transmission potential of a pathogen is influenced by a complex array of factors including pathogen genetics, host ecology, host distribution and host genetics as well as wider environmental factors[4] and, in particular, the human-mediated movement of infected plant material. An emerging risk (European Food Safety Authority (EFSA), 2012) can result from the following:

- A newly identified plant threat for which a significant probability of introduction and geographical spread may occur.
- An unexpected new or increased probability of introduction or spread of an already known agent, for example as a consequence of new trade (for example, pinewood nematode, *Bursaphelenchus xylophilus*) or new agricultural policy.
- A new or increased susceptibility of host plant or extended host range to a known agent (for example, the recent host range expansion of the wheat powdery mildew, *Blumeria graminis*, to triticale (Walker et al, 2011; Troch et al., 2012)) or to an agent with altered virulence (including insensitivity to previously effective control measures).

Risks may emerge as a consequence of the introduction of new crops into the EU, for example to generate biofuels or other applications in the bioeconomy. Also, a new variant of an established pest or pathogen may be potentially more damaging than an exotic introduction and, thus, there is need to use the techniques of the molecular biosciences to provide new insight into pest and pathogen identity.

There is need for more knowledge and awareness to be generated about viruses and phytoplasma residing in wild plants because small changes in local climatic conditions may alter the life cycle of their vectors, causing spread of these pathogens to crop plants. Infections in plant cultivars may be devastating in contrast to the wild host plants in which parasite–host interactions have reached a balance. Introduction of insects belonging to taxonomic groups that contain vectors of viruses or phytoplasma brings risk of new disease problems[5]. Small-RNA deep-sequencing facilitates economically feasible, broad-spectrum detection of viruses in plants and insects and has revealed that wild plants in Europe contain viruses that cause severe disease problems elsewhere but were not known to occur in Europe because wild host plants had not been studied (Bi et al., 2012).

It must also be appreciated that a risk may be exacerbated by change in availability of control methods for known plant pests and diseases; this is likely to be a consequence of recent EU actions on pesticide usage, to be discussed subsequently in this report. Agronomic practice, breeding of improved plant varieties and use of plant protection products have all made their contribution to defending and improving plant health in the EU, but crops and forests may have little natural resistance against newly arrived harmful organisms. Economic impact studies suggest that billions of euros are at stake and the environmental damage may be irreversible (Dalli, in European Commission 2010b[6]).

1.2 Globalisation and increasing impact of climate change

Threats have increased because of globalisation in production systems, trade and travel and the subsequent

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[3] Among the major global crop fungal problems are rice blast (*Magnaporthe oryzae*), black rust of wheat (*Puccinia graminis*), potato late blight (*Phytophthora infestans*), maize smut (*Ustilago maydis*) and soybean rust (*Phakospora pachyrizi*). In addition, there are several examples of fungal pathogens affecting forest trees in the EU with consequences for ecological diversity and accounting for huge losses of fixed carbon dioxide (Fisher et al., 2012). A comprehensive analysis of forest pathogens in an EU-funded project (Santini et al., 2013) reveals a surprising diversity of exotic pathogen species in Europe; most are fungi and most arrive through imports of live plants or wood products and packaging. An extensive list of recent threats in one Member State has recently been published (Tree Health and Plant Biosecurity Expert Taskforce, 2013). Other major pests and diseases are discussed in detail in a Royal Society report (2009) and further scientific, economic and historical review of the most significant bacterial, viral and fungal pathogens has been brought together on http://www.bspp.org.uk/newsphp?id=40. Recent examples of global problems are also discussed by the US Government's Global Hunger and Food Security Initiative: http://agrilinks.org/blog/emerging-plant-diseases-tackling-global-challenges.

[4] These complex interactions are well exemplified in the emerging disease of ash dieback caused by *Chalara fraxinea* (Parliamentary Office of Science and Technology, 2012).

[5] An initiative from the French National Institute for Agricultural Research, INRA (http://www.inra.fr), established to increase public awareness about risks and problems caused by plant diseases and pests, provides an example. Genomic studies have demonstrated that the phytoplasma strains responsible for flavescence doree originated in Europe and already existed in wild plants such as alder and clematis before being introduced into grapevines. The insect vector *Scaphoideus titanus* is from the USA and was probably introduced in France when American rootstocks were imported as part of the fight against downy mildew and phylloxera in the early 20th century and is largely responsible for the rapid spread of flavescence doree in Europe.

[6] Case studies cited by the European Environment Agency (2012) with implications for loss of biodiversity and ecosystem services include the red palm weevil, *Rhynchophorus ferrugineus*, originating in southern Asia and now imparting significant damage to a wide variety of palm species in the Mediterranean area, and the horse-chestnut leaf-miner, *Cameraria ohridella*, possibly originating in the Balkans.

escalation in volume and diversity of plants and plant products entering Member States.

In addition there is accumulating evidence that threats to plant health in the EU are increasing as a consequence of climate change, compounded by other societal and environmental changes, particularly in land use and landscape management (European Commission, 2010a; Pautasso et al., 2012; West et al., 2012). The effect of climate change is exacerbating the other stresses on crop plants and may lead to dramatic yield reductions globally (Royal Society, 2009). Forests across Europe are also increasingly susceptible to climate change and associated infestation-induced tree mortality (Allen et al., 2010).

Climate change is leading to regional shifts in the spread of existing pests and disease but it is not yet clear if it might induce the emergence of something hitherto unknown, a conceptual possibility that has been discussed for the impact of climate change on human infectious disease (EASAC, 2010). Plant health may be affected by climate change through a variety of mechanisms, direct and indirect, arising from accelerated pathogen evolution, shorter disease incubation periods and extended distribution, and enhanced plant stress as a consequence of mismatch between ecosystems and climate and the more frequent occurrence of extreme weather events. A meeting in Portugal of European scientific societies of plant pathology (Boonekemp, 2012) concluded that climate-induced disease can be expected to cause increasing crop losses and decrease the climate-change-mitigation capacity of forests and other natural ecosystems, thereby also exacerbating the impetus to climate change. However, it was considered that sufficiently resilient cropping systems could be developed if there were commitment by the research, policy and industry communities to work together to obtain and translate multi-disciplinary knowledge to adapt integrated pest management to climate change.

The potential impact of bioterrorism (and military conflict) on plant health must also continue to be taken into account. The analysis by the European and Mediterranean Plant Protection Organisation (EPPO, 2007) provides an outline of the issues for Europe with regard to surveillance and intelligence gathering, contingency planning and outbreak management; the current European Commission's Seventh Framework Programme project PLANTFOODSEC is also clarifying the issues for bioterrorism and food security[7].

1.3 EASAC previous work and procedures

In previous work, EASAC has described the value of new breeding approaches and crop genetic improvement technologies in contributing to agricultural innovation (EASAC, 2004, 2011a, 2013) and this work will be cited subsequently. In another series of reports (summarised in EASAC 2011b), EASAC has explored the wide range of issues for tackling human and animal infectious diseases. Many of these issues have their counterparts in plant health, in particular the need for improved surveillance, coordinated preparedness and responsiveness, support for multi-disciplinary research and better linkage with innovative products and services.

This present EASAC work draws on the experience of our Biosciences Steering Panel (http://www.easac.eu/biosciences/steering-panel.html) augmented by expert advice and literature review from members of the EASAC Working Group on 'Planting the Future' (EASAC, 2013) and other invited experts, and informed by a scientific discussion meeting in Brussels in June 2013 (Appendix 1). We have aimed to include sufficient references to help substantiate the points made without attempting an exhaustive bibliography.

The following chapters in this report describe the current EU regulatory situation; what is proposed by the European Commission to upgrade some of the technical control measures; what, in the view of EASAC, is needed alongside the proposed reform; and how science and technology can contribute broadly to the EU goals in tackling risks to plant health.

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7 http://www.plantfoodsec.eu

2 EU regulatory approach to plant health

The general nature of plant health regulation is summarised in Box 1.

2.1 Current situation: weaknesses and objectives

The CPHR can demonstrate significant achievements (Food Chain Evaluation Consortium (FCEC), 2012) but has only been partly effective in preventing the entry, establishment and spread of harmful organisms in the EU, as discussed in the preceding chapter. There is need to strengthen quarantine systems in the ports of entry to the EU and in the related inspection and production systems in exporting countries. Furthermore, EU policy has struggled to reconcile the objectives for increased plant protection with strategic needs to facilitate international trade. Decision-making has been criticised as too slow and border inspections of plant material were often poorly targeted (Macleod et al., 2010). Sometimes it has only been after new threats were established that risk management measures were applied. In necessarily focusing on trade in plants and plant products, legislation has not properly addressed the emerging problems occasioned by natural dispersal and movement of pests, diseases and their vectors in a number of cases.

The previous emphasis has been on organisms that were recognised threats, but it was advised (FCEC, 2012) that the EU must now pay more attention to exotic species, not yet known to be harmful for the EU and to new trade partners and trade routes where there has been little prior scrutiny (Macleod et al., 2010). As the EU expands, an increasingly diverse range of pests, climatic challenges and trade routes will have to be addressed. In the view of

Box 1 Plant health regulation: creating the framework for risk assessment and risk management

- At the global level, the International Plant Protection Convention (IPPC) aims to prevent the introduction and spread of pests of plants and plant products, and promote appropriate control measures. The IPPC functions primarily to standardise risk analysis, share information and provide technical assistance and the IPPC sets its reference standards under the overarching World Trade Organization Agreement on the Application of Sanitary and Phytosanitary measures. The global regulatory framework attempts to standardise tools and pathways but not necessarily the classification of pests: an emerging pest in one region may be an established problem in another region.
- Plant health legislation developed by IPPC-contracting partners is expected to define the institutional framework necessary for effective plant protection, while allowing countries to implement their obligations to facilitate international trade and encourage cooperation and research. It is agreed that support for the objectives and activities of the IPPC is of continuing importance for the EU (Council of the EU, 2012).
- Within the European Community, plant health was initially a national responsibility but subsequently the European Commission Plant Health Directive 77/93/EC and then Directive 2000/29/EC enabled Member States to work together to regulate imported plant material, restricting imports where necessary. With the introduction of the internal market, the concept of plant passports was agreed to allow free movement of plants and plant products between Member States. The Community Plant Health Regime (CPHR) aims to contribute to sustainable production and agricultural competitiveness, protect the natural environment and contribute to food security.
- The EU is advised on relevant scientific issues, including specific risks of pests, by the independent bodies the European and Mediterranean Plant Protection Organisation (EPPO) and the EFSA. The European Commission (DG Sanco) is also supported by its Standing Committee on Plant Health with regard to measures planned and the implementation of adopted legislation. Some Member State regulatory agencies have significant research capacity: to improve methods of pest detection, identification and diagnosis; to evaluate threats from exotic pests by risk assessment; to identify new research needs to reduce uncertainty in risk assessment; and to evaluate risk management measures.
- In 2008, the European Commission decided that the CPHR needed to be evaluated in preparation for the introduction of a new EU plant health law. This revision was triggered in part by several major emerging threats not successfully countered by the current Regime, including red palm weevil around the Mediterranean, pinewood nematode spreading within and from Portugal, *Diabrotica virgifera* spreading in maize and *Phytophthora ramorum* in trees and ornamental plants. The revision is part of the larger efforts to revise and integrate controls in the agri-food sector across plant health, animal health and plant reproductive material.

References: Peralta, in European Commission 2010b; Macleod et al., 2010; POST, 2011; Food Chain Evaluation Consortium (FCEC), 2012; http://www.efsa.europa.eu; www.eppo.int.

EASAC, many new problems may emerge in this era of growing international mobility of humans, plants, pests and pathogens. Gathering the knowledge to assess risks and develop new control methods must receive greater priority both at the EU and at Member State levels to prepare better for those new threats that have potential to cause significant disruption and economic loss in agriculture, horticulture and forestry.

Contributors to the European Commission's review of the current CPHR have noted that the regulatory framework must be reformed to improve contingency planning, with sufficient flexibility to cope with the increasing challenges to plant health from international commerce and environmental change together with possible new challenges, for example bioterrorism. Introduction of targeted regulatory reform must also be accompanied by allocation of sufficient resources (in particular, for risk assessment and quarantine systems) to ensure effective implementation of the technical objectives (Macleod et al., 2010; FCEC, 2012). In addition, resources need to be allocated to encourage cooperation between plant health inspectorates in different Member States and between plant health and customs services[8].

In the view of EASAC, there should also be greater policy coherence to resolve tensions between the objectives for plant health and trade. In addition, the EU could actively encourage more collaboration with non-EU countries through multilateral links to identify plant health threats, as well as making new commitment to raise the currently low public awareness of the threats posed by plant pests and pathogens. It is also fundamentally important to ensure that the necessary scientific infrastructure – encompassing research and scientific advisory capabilities – is put in place to support modernisation of the surveillance and regulatory systems. The activities of the authorities involved in detection and control of newly emerging pests and diseases would be strengthened by increasing the contribution from university departments and public research institutes working in this area. A high proportion of the threats have been identified by these organisations and additional funding for these activities would be helpful.

2.2 The European Commission's proposal to upgrade protective measures against plant pests

In May 2013 the European Commission published its proposal for a Regulation to upgrade the existing plant health regime with legislation aimed to introduce better surveillance and early eradication of new pest species (European Commission, 2013).

In taking account of points made during the consultative phase, the Regulation describes how stronger action is intended against pests defined as a prime priority for the EU with other measures to increase the traceability of planting material. However, some Member States still find the suggestions on how EU-level mechanisms should be introduced to tackle risk assessment and risk management in international trade to be controversial. One other point highlighted by the European Commission in its 'problem analysis' prepared ahead of constructing the Regulation was the need to reinforce the science base underpinning the plant health regime. The new proposal addresses one aspect of this reinforcement in its requirement for Member States to perform surveys in their territory for outbreaks of new and dangerous pests. If applied consistently, this requirement would help to generate standardised and comprehensive data and allow earlier action on the findings. Further specification will be required as the proposed Regulation progresses through the co-decision procedure with the European Parliament and Council of Ministers, to clarify the development of the EU reference laboratory system and standardised diagnostics. The recent draft report from the Committee on Agriculture and Rural Development of the European Parliament (2013) proposes various amendments to the Regulation, including the removal of limits on geographical scope relating to the remoter regions of EU territory and emphasises the importance of ensuring interconnectedness of the Regulation with the IPPC treaty and the leading role of competent national plant protection authorities.

From the perspective of EASAC, the specific actions proposed in the Regulation to simplify and strengthen surveillance and control must be accompanied by other public policy development and implementation across a broad front to ensure more effective protection against emerging plant diseases. Thus, as noted by a recent advisory group in a Member State (Tree Health and Plant Biosecurity Expert Taskforce, 2013), '*the new European plant health strategy needs to cover not just legislation but also co-ordination of research, collection and sharing of information, development of IT systems for import controls, contingency planning, training of plant health inspectors and influencing and using the international standards developed under the International Plant Protection Convention.*' This UK advisory group also made recommendations for action at the country level (Box 2) that, taken together with EU reform, would help to create proportionate measures and systems to lessen the risks to plants, without adding unnecessary barriers to trade and commerce. Other actions necessary to accompany and enhance the impact of this augmented strategy are described in the next chapter.

[8] UK Government Food and Environment Research Agency response to the European Commission proposal to revise legislation. Available on http://www.fera.defra.gov.uk/plants/plantHealth/documents/reviewOfTheECPlantHealthRegime.pdf

Box 2 View from a Member State on action required at the national level

- A coherent programme is required, providing a risk-based approach for prioritisation and preparation for pest and disease threats, coupled with improved governance to enable greater coordination and improved use of science for detection and diagnosis, modelling and rapid information exchange. Actions at the national level would augment the enhanced control of pest and diseases at borders envisaged in EU legislative reform. Individual recommendations covered the following topics.

- Creation of a national risk register for plant health, overseen by a Chief Plant Health Officer (analogous to Chief Veterinary Officer) who is responsible for the strategic prioritisation of resources. Risk assessment would prioritise those organisms that pose the greatest threat of incursion and establishment with highest environmental, social and economic consequences, taking account of the potential for prevention of entry or eradication and the mitigation of effects. Integration of the national efforts would help to support coherence at the EU level to develop and implement procedures for preparedness and contingency planning to predict, monitor and control the spread of pests and pathogens.

- Improving current systems for faster exchange and use of epidemiological and other intelligence from other Member States and other regions; sharing epidemiological models for prediction and analysis of pest and disease spread and comparison of mitigation strategies as the basis for focused and coordinated action throughout the EU.

- Addressing key skill shortages, in particular for understanding the taxonomy and biology of organisms considered to present high risk to plant health; epidemiology, surveying and surveillance; new detection technologies, management, mitigation and adaptation strategies, including plant breeding; biological and chemical control methods; and the social sciences.

- Developing user-friendly systems to provide fast access to coordinated information about plant health, including support for greater public awareness.

Reference: Tree Health and Plant Biosecurity Expert Taskforce, 2013. The remit of this UK advisory group required focus on tree health but many of the conclusions also apply to plant health in agricultural and horticultural crops and of urban and wider environments.

3 What else is needed to protect plant health from emerging pests and diseases in the EU?

3.1 Scientific infrastructure

If the reform of the CPHR is to be successful in protecting agriculture, horticulture, forestry and the broader environment, then the proposed enhancement of risk analysis, technical capacity and quarantine procedures in the new Regulation must be supported by scientific infrastructure and resources. In addition to clarifying what additional research is needed in support of the objectives of the Regulation, there is a broader agenda that has to encompass fundamental and applied research and provide the training and generation of skills needed to ensure continuing excellence in research and use of research outputs to support the linked objectives of surveillance, prevention, control and community education.

Thus, to be effective, the necessary broader, multi-disciplinary, research strategy must be accompanied by a pan-European action plan to translate the outputs from research to support innovation. Plant health is an integral part of production systems, meriting coordinated policy and research that encompasses broader thinking on healthy plants. For example, there is need to extend the research directions that are leading to conceptual changes in understanding the role of the microbiota. The broader research programme should cover the following:

(1) Pest and disease diagnosis (detection, identification and characterisation).

(2) Biology, ecology, epidemiology and spread of plant pests and pathogens and their relationships with hosts and vectors, including wild plant species acting as potential reservoirs of pathogens to cultivated plants.

(3) Plant pest and disease resistance.

(4) Biological and cultural strategies for sustainable pest and disease management.

(5) Evaluation of how healthy plants live in association with microbes that provide direct or indirect benefit.

Although many of these research topics are already covered within the EU, discussion by the EASAC group of experts (Appendix 1) indicated that research effort is often fragmented and research outputs may not be used effectively to inform preparedness and responsiveness. As part of the improving coordination in generating and using research resources, there is need to continue the commitment to develop shared infrastructure for example biomarker databanks and to cooperate with countries outside the EU in collecting and analysing pests and pathogens that are potentially a threat to the EU.

The European Plant Science Organisation (EPSO) recently provided detailed input to advising on the scope of the European Commission's Horizon 2020 Work Programme. Key points for plant health research are summarised in Box 3, and this broad agenda can contribute significantly to strengthening the necessary science base with which to address emerging risks. Although the research activities listed in Box 3 encompass objectives additional to those specific to 'emerging risks of pests and pathogens', it is important to take account of what is needed for the integrated plant health research and innovation agenda. In their contribution to defining what should be included in Horizon 2020, the EU-funded phytosanitary ERA-NET EUPHRESCO (http://www.euphresco.org) identifies some specific examples of phytosanitary research needed to manage new plant health threats in seed potatoes and the harmonisation and validation of fruit plant pathogen testing as well as the broader strategic objectives[9]. The European Cooperation in Science and Technology (COST) programme domains in food and agriculture and in forestry and environment are also providing significant support for trans-disciplinary research networks on key issues[10].

Specific research topics for the study of pests and diseases, for plant defence mechanisms and for resolving uncertainties relating to the impact of climate change (on pests, diseases, vectors and hosts) are discussed extensively in the scientific literature (see, for example, Allen et al., 2010, Jeger & Pautasso in European Commission, 2010a, Boonekemp et al., 2012, Pautasso et al., 2012). It should also be acknowledged that there is potential for increased participation by all stakeholders in long-term data collection to support new epidemiological research, involving amateur naturalists and the general public, as well as public- and private-sector researchers (EFSA, 2012). In addition, as observed in Box 2, significant effort is needed to use the research evidence for modelling, prediction and extrapolation. Assessing which harms are likely to increase as a consequence of climate change requires coupled crop disease–weather interaction models using climate change scenarios (see, for example, Evans et al., 2008).

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[9] Broad objectives defined by EUPHRESCO for phytosanitary research in Horizon 2020 include (1) new approaches for identification and prevention of introduction of new risks to plants from pests unknown and (2) protection against threats from new pests and invasive plants associated with import and production of renewable resources.

[10] http://www.cost.eu/domains_actions.

Box 3 Objectives for resilient plants: some priorities for research for improved plant health

- *Identification and analysis of genes contributing to pathogen and pest resistance in crops, forest tree species and related wild plant species.* To enhance understanding of potential resistance mechanisms, the underlying cellular and metabolic processes and to serve as a basis for improving resistance.
- *Understanding the mechanisms of optimal defence.* Building on progress from recently identified interactions among signalling pathways involved in plant growth with defence signalling networks, to formulate hypotheses on the regulation of defence responses.
- *Management of mechanisms and genes contributing to pathogen and pest resistance in the field.* Including study of new virulent pathogens overcoming the genetic barriers of resistance and, thereby, shutting off defence mechanisms. Consideration of multifactorial aspects should cover both biotic and abiotic stresses.
- *Development of biological control strategies.* Improved understanding of the components of the agro-ecosystem and their interaction is a prerequisite for effective biocontrol, with the potential advantage over chemical controls of not leaving residues and not inducing resistance to the control agent.
- *Genome sequencing of all major European plant pathogens.* To contribute to understanding of pathogenicity and plant defence mechanisms, as well as aiding in development of disease-resistant plants and anticipating future threats. Genome sequencing will also be most helpful for development of accurate, species-specific or pathogen group-specific diagnostic tools. This requires expansion and coordination of those collections of plant pathogenic micro-organisms (fungi and bacteria) that already exist in some Member States. Large-scale deep-sequencing methods used in genomics research are powerful tools for the detection of unknown viruses and unculturable microbial pathogens.
- *Inventory of symbiotic and other beneficial micro-organisms in the rhizosphere*. A huge diversity of soil microbes includes many with beneficial functions such as N-fixing prokaryotes but also mycorrhiza and other micro-organisms and fungal endophytes that act as crop protecting agents. There is large scope for fundamental research and an inventory of beneficial micro-organisms provides the basis for further assessment of the impact on crop production and protection against pathogens. Similarly, an inventory of the phyllobiome (micro-organisms in and on leaves) would also be an important resource to support further research.
- *Inventory and exploitation of molecules released by plants into the soil and atmosphere*. A basis for potential biotechnological applications for protection against pathogens and pests as well as the attraction and colonisation of beneficial micro-organisms and insects and the protection of the habitat against invasion by other plant species.
- *Improving metabolomics' tools, functional genomics and bioinformatics*. Tools required to characterise the inventory of molecules of interest, to measure environmental consequences and to develop improved agricultural practices.
- *Precision farming and plant protection.* Requires improvements, for example, in pest diagnostics, forecasting and risk assessment to extend current work to a broader range of organisms. Improved targeting, enabling differential application of plant protection products, requires use of modern sensory equipment and algorithms, including image analysis, pattern recognition and neural networks.
- *Cropping-systems' approach implementing plant-host resistance and agronomic management practices.* Using research findings on pathogens, insects and weeds and on host-pathogen interactions to devise novel management approaches at the farm level, for example for mixed cultivation systems.
- *Post-harvest protection.* To include methods for early detection and control as well as sustainable methods for prevention.

Source: European Plant Science Organisation (EPSO)/Plant ETP input towards the Horizon 2020 Work Programme 2014-16, 22.5.2013 and EASAC discussion

A concerted research network across disciplines is crucial in preparing and responding to the introduction and spread of new threats to plant health in the EU and to ensuring that the EU plays its proper role in global strategy development. The control of movement of pathogen and insect pests determined by the scope of the European Commission's Regulation should also be accompanied by commitment to improving plant health in other ways: by decreasing the vulnerability of plants and ecosystems and by mitigating the impact once a hazard is established. As outlined in Box 3, this may require research to identify new approaches to developing improved, resistant, plant varieties and introducing new crop/forestry protection and control measures.

It is important to emphasise that no single approach is a panacea for protection of plant health from emerging threats and all technological options must be kept open: new approaches must be integrated within good agronomic practice.

3.2 Pesticides and other crop protection methods

The use of chemical approaches in sustainable crop protection has been discussed in detail elsewhere (see, for example, Smith et al., 2008; Royal Society 2009; Enserink et al., 2013). Reduction in chemical pesticide use has potentially important implications for the health of farmers using pesticides and for the general public consuming food grown with pesticides[11]. Another major problem with pesticides is their lack of selectivity such that they do not discriminate between beneficial and pathogenic organisms. For fungicides, the problem is compounded by the high levels that have customarily been used, leading to accelerated rate of genetic change in pathogen populations and evolution of fungicide resistance, that has reduced the effective agents of control, for example for wheat (Cools & Hammond-Kosack, 2013) and potato (Cooke et al., 2012).

Recent introduction of EU pesticide legislation Directive 2009/128/EC, the Plant Protection Products Regulation EC No. 1107/2009 and the implementation of Member State action plans means that fewer approved chemical control options will exist in the future, which has implications for maintaining crop productivity and for the precautions taken to avoid emerging risks. That is, a policy disconnect is emerging where reduction of pesticide use is being implemented without sufficient attention being paid to facilitating alternative methods for protecting crops from pests and disease (for example late blight; further discussion of the issues is covered in EASAC, 2013). One solution is to capitalise on the new opportunities that will be revealed as knowledge increases about beneficial biotic factor interactions (Box 3)[12], providing a rational basis for biocontrol approaches and supporting innovation and competitiveness in the EU. Generally, there is need to develop novel, durable approaches to smarter pest control (likely to require both new agrochemicals and biological controls) and to make better use of science to guide policy decisions on pesticides (exemplified by the current review of controls on neonicotinoid insecticides in the EU (Enserink et al., 2013)).

3.3 Breeding and biotechnology for improved resistance to biotic stress

The detrimental effects of chemical crop protection can be reduced if plant breeders succeed in further improving plant resistance to cope with pathogens, pests and other biotic stresses (Box 3). In the view of EASAC it is essential to make the most of the scientific opportunities for breeding improved plants as part of the solution to tackling the emerging problems, capitalising on the scientific advances that have helped to clarify mechanisms and genes contributing to pathogen and pest resistance (see, for example, Kushalappa & Gunnaiah, 2013; Dangle et al., 2013). Increasing biodiversity will increase plant resilience. Genetic improvement of plants can be accomplished by more precise breeding techniques (for example, marker-assisted selection), by genetic modification to introduce desirable traits and by other, newer, crop genetic improvement technologies. The options for using plant genetic resources and biotechnology to deliver desired crop traits have been described in detail previously by EASAC (2004, 2011a, 2013) and will not be discussed at length here; however, we take this opportunity to reaffirm the importance of considering all possible approaches to improved plant health[13].

It is vital that the EU regulatory system governing the approval and introduction of genetically modified crops is revisited. The present regulatory system is slow, expensive and does not properly take into account the accumulating evidence on benefit and safety of genetically modified crops. There is need to reformulate the regulatory framework to be science-based, proportionate and predictable, addressing benefit–risk and regulating the trait and product, not the technology. The current problems and possible solutions relating to genetically modified plants are discussed in detail in the recent EASAC report (2013). There is also need for urgent action

[11] There is another implication for public health, exemplified by the emerging association documented between azole fungicide use in agriculture and the development of azole resistance in *Aspergillus fumigatus* in hospitals (EASAC, 2009b; Verweij et al., 2009). Invasive aspergillosis is a human infection that is difficult to manage, and around 10% of patients harbour resistant isolates. The use of azole fungicides is common for plant protection: for example, about half of the total EU acreage under cereals and grapevine is treated annually, and repeated application for lengthy periods increases pressure for development of resistance. There is now evidence from across the EU that resistance development against azole fungicide causes cross-resistance to medical triazoles by opportunistic fungal pathogens.

[12] In addition to research to understand beneficial effects of microbes (Box 3), it may be possible to boost plant innate immunity to attack by using natural or synthetic molecules as activators (Royal Society, 2009; Kupferschmidt, 2012; Enserink et al., 2013; Dangl et al., 2013). New approaches to developing agricultural pesticides and biocides are discussed extensively in the work of the OECD (http://www.oecd.org/env/ehs/pesticides-biocides).

[13] Phenotyping rather than genotyping is often the rate-limiting step in the implementation of new breeding approaches. Advances in near-range remote sensing techniques may enable high-throughput screening of plant disease-resistance traits in the field (Mahlein et al., 2012). Taken together with other advances in high-throughput analysis (Royal Society, 2009), there is considerable potential for accelerating innovation.

to agree the status and regulation of new breeding techniques (EASAC, 2013), in particular to confirm which products do not fall within the scope of legislation on genetically modified organisms.

3.4 One Health

As noted in the previous sections, improved plant health globally will have beneficial consequences for human health in various ways, including through increased food security, better nutrition and reduced pesticide use. Other human health considerations also merit attention. For example, some fungi have broad host range (human, animals and plants) and it is conceivable that fungi that are not currently pathogenic in humans could jump the species barrier (Institute of Medicine, 2011; Kupferschmidt, 2012).

There is increasing interest in including plant health within the current developments that focus on building strategic linkages between human and animal health. Taking this ambitious, comprehensive, approach to 'One Health' (Institute of Medicine, 2011) has multiple implications: for understanding ecology, constructing surveillance networks, international regulation and coordination, introduction of innovative detection, diagnosis and modelling tools and clarification of the role of asymptomatic carriers and sentinel species and, as discussed previously, for elucidation of the effects of beneficial microbes in supporting plant health. The goal for public/veterinary/plant health management systems to share common principles and objectives for the science-based management of all relevant risk requires better collective elucidation (Institute of Medicine, 2011).

4 Maintaining the momentum in tackling risks to plant health

In the view of EASAC, it is necessary to take a broad view of the strategic needs to improve and sustain plant health. Surveillance of imports and quarantine systems are vital but need to be science based and technically justified. All the necessary actions depend on excellent scientific infrastructure and coordination. There is need for better understanding of the interaction between plant host, pathogen or other pest, and the wider environment, across regional and global scales. The integrated response to risk should include evidence from epidemiology, climate forecasting, genomic surveillance and evaluation of molecular evolution. Just as in human and animal health (EASAC, 2011b), so in plant health, it is essential to prepare for the unexpected in considering those organisms not yet known to be harmful, for example by using analysis of species traits to identify potential threats (Macleod et al., 2012). However, the lack of an evidence-based and proportionate regulatory framework for approval of new plant traits, which can act to encourage innovation, is a serious deficit that should be remedied (EASAC, 2013).

4.1 Recommendations

Pan-European strategy development must use sound science to inform policy and innovation. The matters addressed in this report are relevant to agriculture, horticulture and forest crops as well as to plants in natural habitats. A multi-disciplinary, evidence-based approach should encompass a broad range of actions including those to analyse and tackle the effects of globalisation (particularly climate change and the potential for bioterrorism) on plant health; model disease emergence and spread; implement rapid monitoring and detection systems; provide mechanisms for evidence sharing; support public education and engagement; give good governance to promote agricultural, horticultural, forest and environmental sustainability. This requires much better networking across the various domains and must be accompanied by renewed commitment to research on plants, their pests and diseases and vectors. Implementing an EU strategic focus on emerging plant diseases would facilitate this concerted research, help to provide the knowledge base for national and European regulatory agencies, and contribute to the international advancement of pest and disease control.

Specific actions proposed by the European Commission to simplify and strengthen the legislative framework and, thereby, manage the entry, establishment and spread of harmful organisms require scientific support and must take account of specific regional strategies required to deal with a range of climatic ecotypes and agricultural, horticultural and forest systems throughout the EU. In addition, they must also be part of a wider strategy to ensure effective protection against current and emerging plant pests and diseases. As well as being comprehensive, the strategy must also be sufficiently flexible to cope with the increasing and varying threats from international trade, climate change and other challenges.

EASAC recommendations for further discussion and action in developing and using tools, techniques and practice are as follows.

Surveillance systems

- Monitoring of pathogens and other pests must be improved, in support of the European Commission's technical objectives and Member State recommendations (Box 2). This must cover monitoring both for imports and spread within the EU and must be accompanied by establishment of effective early warning systems. Effort cannot be confined to plant and plant products but must also include, for example, wood packaging material.

- Long-term, longitudinal, biological data recording must be continued over sustained periods, possibly linked with biodiversity survey data and involving surveillance efforts by the citizen as well as by public and private sector researchers. There must also be better linkage between pest and other databases (EFSA, 2012) for collective analysis at national, regional and international levels. This has implications for standardisation of quality of datasets and methodologies.

- It is possible to capitalise on new forms of monitoring and reporting, in particular the social and other media[14]. The development of approaches and tools to identify emerging risks within large datasets can usefully draw upon lessons learnt in monitoring of human infectious diseases, for example in syndromic surveillance (EASAC, 2011b).

- The relatively high economic value of crops has meant that detection of disease in agriculture outpaces that in wild species in natural habitats. The growing significance of harm outside of the managed agricultural environments and the realisation of the

[14] For example, the European Media Monitor system MedISys, a joint initiative between the European Commission's Joint Research Centre and EFSA, http://www.emm.newsbrief.eu/overview.html

value of plant health in a wide range of ecosystem services (EASAC, 2009a) requires a higher political and public profile (Fisher et al., 2012).

- The potential issues for plant health associated with bioterrorism and military conflict must continue to be taken into account.

Research and training

- Some specific research priorities have been discussed in previous sections (Box 3); we reiterate here the importance of reducing fragmentation in research capacity and priority-setting, the opportunity to extend research directions and the need for EU coherence and sustained critical mass in pursuing agreed objectives. The recommended scope should include pest and disease diagnosis; biology, ecology and epidemiology of plant pathogens and their relationships with hosts and vectors; plant pest and disease resistance; biological and cultural strategies for sustainable pest and disease management; and evaluation of how healthy plants live in association with microbes that provide direct or indirect benefit. New grant schemes should be considered to ensure that relevant work in universities and public research institutions is appropriately coordinated with the activities of the plant health authorities.

- The capacity to engage in research and to use research outputs in the EU is becoming limited by shortage of skills in pivotal disciplines, including taxonomy, plant pathology and various other disciplines (Box 2 and EASAC, 2013). For example, a recent audit in the UK[15] of plant pathology training and education documents how a decline in teaching is threatening Member State ability to combat new risks to crops. The European Commission may wish to consider supporting training on the different groups of plant pests and diseases by an initiative analogous to that introduced by the US National Science Foundation: the Partnerships for Enhancing Expertise in Taxonomy[16].

- There are continuing opportunities for the EU to develop critical mass in collaborations for a common research agenda between Member States and in using the available research in support of policy development and implementation. The ERA-NET initiative EUPHRESCO that has involved Member States as well as the European Commission, EFSA and EPPO has played useful roles in evidence collection and coordination. The European Commission should explore options for continuing and broadening this collective activity for plant health and extend the international research links. It would be valuable for the European Commission to assign greater priority to research issues in plant health in Horizon 2020 (see Box 3), given the rather limited attention in the Seventh Framework Programme plant research portfolio[17].

It is also important to ensure that research issues for plant health are appropriately addressed and aligned within the two new European Commission initiatives: (1) the Joint Programming Initiative 'Agriculture, Food Security and Climate Change' (http://www.faccejpi.com) and (2) the European Innovation Partnership 'Agricultural Productivity and Sustainability' (http://ec.europa.eu/agriculture/eip/index_en.htm). Both these ventures offer the potential to involve a wide range of stakeholders and connect researchers with research users.

Innovation and regulation

- It is critically important to assign higher priority to the better use of research advances in support of innovation and the translation of knowledge from research centres to practical applications in support of plant health.

- New durable, control approaches are needed to overcome the current limitations of pesticides and to respond to the challenges introduced by EU pesticide product legislation that reduces the number of approved chemical control options.

- There are very significant opportunities for breeding improved plants durably resistant to biotic stress. Genetic improvement can be accomplished by more precise breeding techniques (for example, marker-assisted selection), by genetic modification to introduce desirable traits and by other, newer, technologies to improve crop genetics.

- There is need for a rapid, efficient and robust system to identify emerging risks as early as possible, and to assess, communicate and tackle those risks. At the same time there is need to coordinate the European Commission's regulatory and innovation-support roles. With regard to plant health surveillance, this means that the plant health regulatory framework has to be informed by the latest various scientific developments, including taxonomic advances in identification, network epidemiology and digital diagnostics (Pautasso et al., 2012). For developing better pest and disease resistance, this means that the regulatory framework for approving new crops developed using genetic improvement technologies has to focus objectively on the scientific evidence for benefit–risk for the product and trait (EASAC, 2013)

15 British Society for Plant Pathology (2012) on http://www.bspp.org.uk/society/bspp_plant_pathology_audit_2012.php
16 http://www.nsf.gov/funding/pgm_summ.jsp?pims_id=5451
17 Listing of current research projects on http://www.epsoweb.org/fp7-plant-health-research-projects-O

and the registration, regulation and availability of chemical pesticides and other control measures must also be based on sound science.

The issues to be faced are scientific, technological and regulatory, but they cannot be tackled successfully without also raising political and public awareness of the importance of plant health. In completing this report, EASAC draws attention again to the commonality of the principles for plant health and for human and animal infectious disease. We repeat the advice that EASAC published previously in our work on public health (EASAC 2011b), whose general principles are equally applicable to plant health:

'*In our view, the common elements required to inform policy development across a broad front are the generation and use of knowledge. Research is important in multiple ways: as the basis for improving health service practice, as the resource to support innovation and education, and in furnishing the evidence base for the policy-maker. The EU must be more ambitious in capitalising on its scientific capabilities and leadership and in building new linkages between academia, industry, health services and politics.*'

In conclusion, research is leading to rapid advances in diagnostic technologies, surveillance and communication methodologies and to increasing understanding about the current and emerging threats to plant health and the means to protect and promote plant health. There is great scope for the scientific community to work with regulators and other stakeholders to generate the necessary public and political visibility for these issues and to provide a sound and flexible framework for risk analysis and risk management. New opportunities are now coming within range for identifying and implementing innovative approaches to supporting and sustaining plant health and to preparing for future challenges.

Appendix 1 EASAC scientific discussion meeting

This Statement draws on points raised in discussion at a meeting organised by EASAC in Brussels in June 2013 with invited experts, from across a range of scientific disciplines, acting in an independent capacity:

Volker ter Meulen (Chair, Germany)
Walter Alhassan (Ghana)
Eva-Mari Aro (Finland)
Ervin Balazs (Hungary)
Claudia Canales (United Kingdom)
Ian Crute (United Kingdom)
Torbjorn Fagerstrom (Sweden)
Richard O'Kennedy (Ireland)
Maria Salome Pais (Portugal)
Ole Petersen (United Kingdom)
Joachim Schiemann (Germany)
Paul Schulze-Lefert (Germany)
Tomasz Twardowski (Poland)
Jens-Georg Unger (Germany)
Jari Valkonen (Finland)
Eva Zazimalova (Czech Republic)
Robin Fears (EASAC secretariat, United Kingdom)

EASAC thanks these independent scientists for their participation in the meeting and their continuing involvement in drafting the Statement. EASAC also thanks the other members of the Biosciences Steering Panel for their review of the initial project scope and objectives.

List of abbreviations

CPHR	Community Plant Health Regime
EASAC	European Academies Science Advisory Council
EFSA	European Food Safety Authority
EPPO	European and Mediterranean Plant Protection Organisation
EPSO	European Plant Science Organisation
EU	European Union
FCEC	Food Chain Evaluation Consortium
FERA	Food and Environment Research Agency
IPPC	International Plant Protection Convention

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