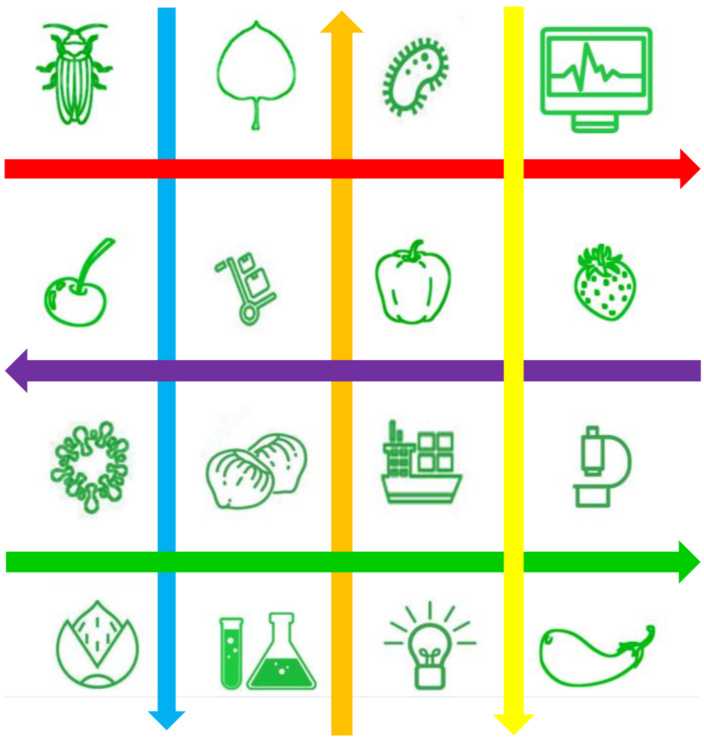
Euphresco Strategic Research Agenda

2017-2022



Plant health research co-ordination, cross-sectoral collaboration and learning

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Terms and definitions

Commodity	A type of plant, plant product, or other article being moved for trade or other purpose [ISPM No. 5]
Consignment	A quantity of plants, plant products and/or other articles being moved from one country to another and covered, when required, by a single phytosanitary certificate (a consignment may be composed of one or more commodities or lots) [ISPM No. 5]
EPPO	European and Mediterranean Plant Protection Organization
ERA-Net	European Research Area – Networking, element of the FP6 specific programme aiming at integration and strengthening the European Research Area via coordination and mutual opening of national and regional research programmes
Euphresco	International network for phytosanitary research coordination and funding. Acronym for 'European Phytosanitary Research Coordination'
Inspector	Person authorized by a National Plant Protection Organization to discharge its functions [ISPM No. 5]
Introduction	The entry of a pest resulting in its establishment [ISPM No. 5]
IPPC	International Plant Protection Convention, as deposited with FAO in Rome in 1951 and as subsequently amended [ISPM No. 5]
ISPM	International Standards for Phytosanitary Measures [CEPM, 1996; revised ICPM, 2001]
NAPPO	North-American Plant Protection Organization
NPPO	National Plant Protection Organisation; official service established by a government to discharge the functions specified by the IPPC [ISPM No. 5]
Official	Established, authorized or performed by a National Plant Protection Organization [ISPM No. 5]
Pathogen	Micro-organism causing disease [ISPM No. 3, 1996]
Pathway	Any means that allows the entry or spread of a pest [ISPM No. 5]
Pest	Any species, strain or biotype plant, animal or pathogenic agent injurious to plants or plant products [ISPM No. 5] Here: including invasive non-native plants
Pest risk analysis (PRA)	The process of evaluating biological or other scientific and economic evidence to determine whether a pest should be regulated and the strength of any phytosanitary measures to be taken against it [ISPM No. 5]
Phytosanitary measure	Any legislation, regulation or official procedure having the purpose to prevent the introduction and/or spread of pests, or to limit the economic impact of regulated non-quarantine pests [ISPM No. 5]
Phytosanitary procedure	Any official method for implementing phytosanitary measures

	including the performance of inspections, tests, surveillance or treatments in connection with regulated pests [ISPM No. 5]
Phytosanitary regulation	Official rule to prevent the introduction and/or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests, including establishment or procedures for phytosanitary certification [ISPM No. 5]
Plant pest	See: pest
Plant products	Unmanufactured material of plant origin (including grain) and those manufactured products that, by their nature or that of their processing, may create a risk for the introduction and spread of pests [ISPM No. 5]
Plants	Living plants and parts thereof, including seeds and germplasm [ISPM No. 5] It shall also include alien plants
Plants for planting	Plants intended to remain planted, to be planted or replanted [ISPM No. 5]. It includes categories such as bare root plants, rooted plants, bulbs and tubers, cuttings, budwood and graftwood and meristem tissue culture
PRA	Pest Risk Analysis
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled [ISPM No. 5]
Research	Includes basic and applied research and experimental development as defined by the OECD (OECD Frascati Manual, 2002). Activities excluded from the definition of research are also defined by the Frascati manual
Regulated pest	A quarantine or a regulated non-quarantine pest [ISPM No. 5]
Stakeholders	Anyone with an interest in plant health e.g. commercial firms, private organisations, funding bodies, land owners or general public
Test	Official examination, other than visual, to determine if pests are present or to identify pests [ISPM No. 5]
Treatment	Official procedure for the killing, inactivation or removal of pests, or for rendering pests infertile or for devitalisation [ISPM No. 5]

Introduction

Plants are an important part of our daily environment. They are relevant economic goods, provide nutrition, shape our living environment and influence the living culture. Agriculture, horticulture and forestry provide food, plant products and raw materials, while ornamental plants contribute significantly to our quality of life.

All plants encounter different enemies in their natural habitat, from pests like aphids or beetles, to diseases caused by fungi, bacteria or viruses. These pests and diseases constitute a natural component of the environment. A broad range of plant health defence mechanisms allow plants to cope with these challenges, while biological or chemical agents are available to enhance protection against native pests and diseases.

However, while plant pest and diseases relied on natural mechanisms for dispersal in the past, human trade and transport have opened new opportunities for rapid global dispersal. As a consequence, growers have to face increasing problems arising from the introduction and spread of new economically or environmentally damaging plant pests, diseases and invasive species. Very often, knowledge on their epidemiology, their behaviour in a new environment or on a new host, their dispersal potential as well as their impact and effects of eradication, containment and control measures is limited.

To avoid extensive damage to society, the economy and the environment, we need measures that preferably prevent the entry into a new area of a pest not present in that area or, in case of pests recently entered in an area, to prevent their establishment and spread into other areas. These measures may consist of legal restrictions (regulations) which limit the import of specific plants or plant parts, as well as procedures to eradicate newly introduced pests as soon as possible and to control and contain them to avoid further spread. These measures are supported by pest risk analysis to estimate the potential emanating risks as well as research on the biology of the pest and possible containment and eradication measures. The complex of all these measures and procedures is integrated under the term Plant Health, for legislative restrictions the term Plant Quarantine is used (see Terms and definitions).

A well-known historical example of the impact of a new pathogen is potato blight caused by *Phytophthora infestans*. Its introduction caused the Great Famine in Ireland in the 19th century. Dutch elm disease which decimated elm populations in Europe during the 20th century, provides an example of the devastation of the natural environment. More recent threats to plant health include *Diabrotica virgifera*, a leaf beetle originating from Central America, considered as one of the most destructive pests of cultivated corn *Zea mays* L.: corn rootworm infestations have been shown to decrease yields of maize by 10–13% and control costs have been estimated to be one billion dollars in the U.S. alone. The bacterium *Xylella fastidiosa* is causing serious damage to olive groves in Puglia (Italy). Since 2012, various European countries have reported interceptions of infected coffee plants from Latin America. The current outbreak in olive trees in Southern Italy and the presence of the bacterium in several Mediterranean plant species in Southern Italy and Southern France constitutes an important change to its geographical distribution and exposes new host plants to its damaging effects. These are only few examples of newly introduced or invasive pests.

The rate of entry and establishment of new, economically or environmentally damaging plant pests, diseases and invasive species is constantly increasing worldwide as trade of plants and plant products becomes more global with increasing volume and diversity. These problems may be exacerbated by climate change, which may increase the ability of some pests to establish and spread. It is the role of Plant Health to protect plants from these new emerging or expanding threats.

Research has a key role in underpinning plant health activities, ranging from pest risk analysis, regulation, surveillance, taxonomy, diagnostics and actions at outbreaks to eradicate the pests and control further spread (containment, certification). It also helps to maintain and develop scientific expertise and infrastructures that support plant health. In this context, the Euphresco network (**Eu**ropean **Ph**ytosanitary **Res**earch **Co**operation) has contributed to the coordination of national research activities. Initiated by the EU Council Working Party of Chief Officers of Plant Health Services (COPHS) and initially funded through the 6th and 7th EU framework programmes, Euphresco has now evolved in an international network hosted within the European and Mediterranean Plant Protection Organization (EPPO). As of January 2017, the network is composed of programme owners and managers in 55 countries in the APPPC, EPPO and NAPPO regions: Albania, Algeria, Australia, Austria, Azerbaijan, Belarus, Belgium, Bosnia and Herzegovina, Bulgaria, Canada, Croatia, Cyprus, the Czech Republic, Denmark, Estonia, Finland, France, Georgia, Germany, Greece, Guernsey, Hungary, Ireland, Israel, Italy, Jersey, Jordan, Kazakhstan, Kyrgyzstan, Latvia, Lithuania, Luxembourg, Republic of Macedonia, Malta, Mexico, Moldova, Morocco, the Netherlands, Norway, Poland, Portugal, Romania, the Russian Federation, Serbia, Slovakia, Slovenia, Spain, Sweden, Switzerland, Tunisia, Turkey, Ukraine, the United Kingdom, the United States of America, Uzbekistan.
The main over-arching strategic aims of Euphresco are: a) to better coordinate national and regional plant health research programmes; b) to provide better research support for policy and operations through transnational cooperation and collaboration (e.g. trans-national research projects) that optimises limited funds; c) to better support phytosanitary science capability through such transnational activities and research projects.

This common research agenda was developed to set the research priorities that Euphresco members will support over the next 5-10 years (through their national and transnational research activities) in order to help protect agriculture, horticulture, forestry and the environment from quarantine and emerging new pests; it will set a common ground to increase coordination and co-operation between nationally-based, regional and international phytosanitary research programmes. An evaluation of the impact of the research agenda on research coordination and an analysis of how the priorities and objectives herein are addressed will be undertaken in 2022; the content of the document will be amended to take into account the recommendations of the evaluators, in particular to ensure that the agenda covers new needs and adapts to the advances of science. The views of users and regulators will be taken into account as well to ensure that research needs are identified and expressed whenever problems are encountered for which research may provide (part of) the solution.

The document was developed taking into account national research agendas of Euphresco members and suggestions gathered from plant health experts who participated in various EPPO Panels meetings. This approach allowed field and research experience to be combined with national guidance. Stakeholders of the Euphresco Network, the European Commission Directorate of Health and Consumers and the European Food Safety Authority as advisors, the ERA-NET projects C-IPM, Core Organic and SUMFOREST, the European Seed Association (ESA), the International Seed Testing Association (ISTA), the International Seed Health Initiative (ISHI) and the Centre for Agricultural Bioscience International (CABI) were consulted and their views were taken into account. The Strategic Research Agenda was endorsed by the Euphresco Governing Board on the 15th of February 2017 and entered into force on the 10th of March 2017.

The agenda’s core is made of 7 research priorities (and 18 research objectives), that summarise common strategic areas to guide future phytosanitary research. It is not possible to discuss research priorities without considering the researchers that should undertake the activities or the infrastructures needed which at the same time allow research implementation and nurture scientific expertise; the stakeholders that will fund, and/or use and benefit from research outputs are also part of this research ‘ecosystem’ that we tried to capture in this document.

Research infrastructures provide the basis that allows the research community to work on phytosanitary issues. Reliable collections are vital for identification of pest species and development of detection methods. Research would not be possible without laboratory facilities that meet the phytosanitary safety requirements and the experts that operate these facilities. Databases are needed to record basic knowledge on pest species and allow for efficient transfer of knowledge between different laboratories. Some of the priorities on research infrastructure that are identified in this Strategic Research Agenda are not innovative, but nevertheless remain important as the cornerstones on which these innovations are built.

It is not possible to avoid all the challenges to plant health posed by global trade, increasing travel activities and climate change. However, it is possible to optimise strategies to address these challenges with effective cooperation and coordination. There is a need to identify changes to existing or emerging trade routes and to collect information regarding the growing and production practices in exporting countries in order to identify those pathways presenting the greatest phytosanitary risks. Interdisciplinary research is often necessary to identify those pests on which transnational research efforts should focus. Transnational collaboration can provide the best solutions to difficult situations as it enables the efficient use of national research funds and personnel resources by pooling them. Cooperation creates a more diverse and critical mass of expertise to deliver more output compared to that which can be achieved through separate small projects alone. In the context of global trade, phytosanitary research should be global too. Countries around the world may deal with the same harmful organisms, either as native plant pests or as non-native new pests: joining resources can accelerate the development of solutions without increasing the costs supported by each individual country. A pest may have a limited impact in its native environment compared to a new habitat it may reach; transnational cooperation can accelerate the transfer of knowledge in e.g. the biology of an organism and the epidemiology of a plant disease to manage the threats associated with it. Ideally, research related to phytosanitary regulations may benefit from co-operation at the world-wide level or at least with relevant linkages. Cooperation should aim at increasing the visibility of research activities and their outputs and strengthening the links between the different players to be involved in the research activities and infrastructures development identified in this Strategic Research Agenda.

Strategic Research Agenda

Research (R)

Interdisciplinary research is necessary to identify those pests on which transnational research efforts should focus. There is also a need to identify changes to existing and emerging trade routes, to collect information regarding growing and production practices in exporting countries and to develop knowledge on the pest biology in different production conditions in order to guide investigations on possible epidemics and to identify those pathways presenting the greatest phytosanitary risks.

Priority 1[1]: Know your enemy - epidemiology and taxonomy

High-throughput techniques make it easy to generate vast amounts of genetic data. However, this data is most valuable when the biology behind the data is known as well.

Knowledge on the biology and epidemiology of pests, especially for new emerging or re-emerging pests, is often missing or (out)dated. To assess the risk associated with a pest one should know what damage it inflicts, on which hosts, and how it spreads, reproduces and survives. This data is needed to strengthen diagnosis, to support PRA and to develop intervention strategies. Factors that sustain the successful invasion and multiplication of pests should be identified in relation to relevant host plants and environmental conditions. This should be done in light of our understanding that for many microbial pests, pathogenicity is only part of their lifestyle beside an opportunistic or endophytic lifestyle (links to Objective 2017-R-3.2; Objective 2017-R-5.1; Objective 2017-R-5.3). The specificities of pests' physiological states, low population densities or uneven distribution within the plants, but also e.g. their fastidious isolation and/or growth should be analysed. Climate change may significantly influence the establishment of plant pests. Temperature in particular, may induce changes in life-cycle duration (rate of development), number of generations per year, population density, size, genetic composition, host plant use, symptom development as well as local and geographical distribution linked to colonization and extinction. The true detrimental impacts of an organism on the environment and agriculture may become apparent when it finds particularly favourable conditions (e.g. new host species, absence of natural enemies, land use and agricultural practices, habitat suitability, vectors and climatic conditions). This explains why some pests may cause minimal damage in their country of origin, which complicates pest risk analysis. International collaboration and tools for early warning will allow for better prediction of risks. The International Plant Sentinel Network http://www.plantsentinel.org/ is a successful example of a centrifugal (and reciprocal) approach where information gained in one country could contribute to prevent introduction in other countries (and vice-versa) and on which future research should lever (see **Objective 2017-R-1.1**).

Taxonomy and classification are the foundation of regulation (links to Objective 2017-I-1.1; Objective 2017-I-1.2; Objective 2017-I-1.3). Regulated organisms are known and treated based on their taxonomic name which is considered to represent a clearly delineated

[1] The numbering of the agenda's priorities is ordinal and not linked to their importance

biological group with specific characters concerning plant pathology and epidemiology. Taxonomic expertise, which is needed to identify harmful quarantine organisms via their visual characteristics, is gradually decreasing. Several studies performed with advanced technologies reveal that both the historical taxonomic names and the associated pathological features are different from the accepted taxonomy. It is of outmost importance for both regulation and management that expertise is maintained and taxonomy of important quarantine organisms is revisited in interdisciplinary studies (see **Objective 2017-R-1.2**).

Objective 2017-R-1.1: to improve knowledge on the biology, epidemiology and ecology of priority invasive and (re)emerging pests

Objective 2017-R-1.2: to support taxonomic research for the unambiguous identification of pests

Objectives of this priority have been endorsed by: Department of Agriculture and Water Resources (AU); Ministry of Agriculture and Forestry, Environment and Water Management (AT); State Phytosanitary Control Service at the Ministry of Agriculture Republic of Azerbaijan (AZ); Federal Public Service Health, Food Chain Safety and Environment (BE); Institute for Agricultural and Fisheries Research (BE); Walloon Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Canadian Food Inspection Agency (CA); Federal Office for Agriculture (CH); Ministry of Agriculture, Rural Development and Environment (CY); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); Ministry of Agriculture and Forestry (FI); French Agency for Food, Environmental and Occupational Health & Safety (FR); Federal Ministry of Food and Agriculture (DE); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Benaki Phytopathological Institute (GR); Ministry of Rural Development and Food (GR); Department of Agriculture, Food and the Marine (IE); Ministry of Agriculture, Plant Biosecurity, Plant Protection and Inspection Services (IL); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); Ministry of Agriculture (LV); National Sanitary Service, Food Safety and Quality (MX); Ministry of Economic Affairs (NL); Netherlands Food and Consumer Products Safety Authority (NL); Direction-General for Food and Animal Health (PT); Ministry of Agriculture, Forestry and Food (SI); National Institute for Agricultural Research and Food Technology (ES); Department of Agriculture, Animal and Plant Health Inspection Service (US).

Priority 2: Know your enemy - trade impact

Information on trade, place of origin and points of entry are often insufficient to estimate the risks. New commodities and new origins of imported products may pose new and variable risks. Moreover, globalization may open new trade routes around the world which could change the magnitude and frequency of pest introductions. New legislative approaches are being developed. For example, compared to the previous legislation, the new EU plant health regulation will have a greater emphasis on identification and assessment of plants and plant products liable to provide pathways for the introduction of new pests into the EU from third countries (links to Objective 2017-R-3.2; Objective 2017-C-2.1) (see **Objective 2017-R-2.1**).

With regard to the risk of introducing harmful organisms, plants for planting (including seeds) are generally considered as presenting a higher risk of pest introduction than other commodities. First of all, the pests can survive, and possibly reproduce, on their living hosts or in the soil during transport of the commodity. Secondly, once at destination, the plants remain planted or are replanted, facilitating survival and transfer of the pest to a suitable host. Trade of high-quality plants for planting (in particular from a phytosanitary point of view) that fulfil international standards relies on the harmonisation of national legislation and trade regulations. Research is needed to provide scientific evidence to support phytosanitary measures, in particular to understand the mechanisms of disease/pest transmission (links to Objective 2017-R-1.1) and advice on the conditions that lower the risk during production and trade of planting material (see **Objective 2017-R-2.2**). Collaboration with organisations involved in the production, certification and marketing of plants for planting (including seeds) will contribute to safer trade (links to Objective 2017-C-2.1). Assessment and management of risks associated with other pathways will contribute to the development of a holistic view.

Objective 2017-R-2.1: to improve knowledge on emerging pathways of entry and means of spread for pests

Objective 2017-R-2.2: to expand knowledge on transmission of disease and pathogens for healthy planting material

Objectives of this priority have been endorsed by: Department of Agriculture and Water Resources (AU); Ministry of Agriculture and Forestry, Environment and Water Management (AT); Institute for Agricultural and Fisheries Research (BE); Walloon Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Federal Office for Agriculture (CH); Ministry of Agriculture, Rural Development and Environment (CY); Central Institute for Supervising and Testing in Agriculture (CZ); Ministry of Agriculture (CZ); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); Ministry of Agriculture and Forestry (FI); French Agency for Food, Environmental and Occupational Health & Safety (FR); Federal Ministry of Food and Agriculture (DE); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Benaki Phytopathological Institute (GR); Ministry of Rural Development and Food (GR); Department of Agriculture, Food and the Marine (IE); Ministry of Agriculture, Plant Biosecurity, Plant Protection and Inspection Services (IL); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); International Center for Advanced Mediterranean Agronomic Studies (Int); Ministry of Agriculture (LV); National Sanitary Service, Food Safety and Quality (MX); Netherlands Food and Consumer Products Safety Authority (NL); Direction-General for Food and Animal Health (PT); Ministry of Agriculture, Forestry and Food (SI); National Institute for Agricultural Research and Food Technology (ES); State Service of Ukraine on Food Safety and Consumer Protection (UA); Department of Agriculture, Animal and Plant Health Inspection Service (US).

Priority 3: Know your enemy - assessing impact

Pest risk assessment and pest risk management allow quantification of the likelihood and magnitude of risks posed by entry, establishment and spread of pests, their potential economic, social and environmental impacts and identification and evaluation of risk management options. They are founded on sound scientific knowledge concerning epidemiology, biology and ecology of the pests (links to Objective 2017-R-1.1), the availability and distribution of hosts (and their cultural practices) (links to Objective 2017-I-2.3), climatic data, mechanisms and means of spread (e.g. vectors), probability of establishment and socio-economic and environmental consequences. A comprehensive view (links to Objective 2017-C-1.1) on possible economic, social and environmental impacts of a pest based on the abovementioned risk factors and on the feasibility and impact of appropriate phytosanitary measures is often scarce and research is needed to produce and interlink existing and new data (see **Objective 2017-R-3.1**).

In addition to information generated under the research priorities 1 and 2, models on pathways, spatial distribution and potential abundance of pests also support risk assessment and the development and evaluation of risk management options. Models can also be used to estimate the impact of plant pests on crop yield and quality as well as on the environment. In order to become a more regularly used tool for plant health risk managers, models need to be developed and validated and managers need a clear understanding of their potential applicability and limitations. Model development needs to take into account the available evidence, which may be very limited in the case of pests which are not yet present in the risk assessment area. Consequently, models should aim to quantify uncertainties, where appropriate, so that they can be managed effectively. Computational biology and mathematics can be used to integrate transdisciplinary expertise in plant health (e.g. understanding of plant pests, hosts and socio-economic and environmental factors) (links to Objective 2017-C-1.1) (see **Objective 2017-R-3.2**)

Objective 2017-R-3.1: to identify and evaluate (horizontal) risk reduction options (effectiveness, feasibility and cost)

Objective 2017-R-3.2: to develop models to summarise the understanding of the spread, establishment and impact of pests

Objectives of this priority have been endorsed by: Ministry of Agriculture and Forestry, Environment and Water Management (AT); Federal Public Service Health, Food Chain Safety and Environment (BE); Walloon Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Federal Office for Agriculture (CH); Ministry of Agriculture, Rural Development and Environment (CY); Central Institute for Supervising and Testing in Agriculture (CZ); Ministry of Agriculture (CZ); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); Federal Ministry of Food and Agriculture (DE); Ministry of Agriculture and Forestry (FI); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Department of Agriculture, Food and the Marine (IE); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); Ministry of Agriculture of the Republic of Lithuania (LT); Ministry of Agriculture (LV); National Sanitary Service, Food Safety and Quality (MX); Ministry of Economic Affairs (NL); Netherlands Food and Consumer Products Safety Authority (NL); Direction-General for Food and Animal Health (PT); Ministry of Agriculture, Forestry and Food (SI); National Institute for Agricultural Research and Food Technology (ES); State Service of Ukraine on Food Safety and

Consumer Protection (UA); Department of Agriculture, Animal and Plant Health Inspection Service (US).

Priority 4: Find your enemy - improved inspection and surveillance

Inspection of entire consignments is not feasible and the inspection procedure is performed on samples. According to ISPM 31, different sampling methodologies exist (systematic, stratified, sequential, cluster, fixed proportion, etc.) to detect regulated pests, to verify the compliance with phytosanitary requirements or to determine the proportion of the consignment which is infested.

Risk-based sampling combines evidence and statistics to inform inspection strategies that allow us to detect pests and diseases in a more systematic manner, thereby optimising the effectiveness and efficiency of inspection activities. Development and implementation of risk-based sampling methodologies is needed to promote technically justified approached for phytosanitary inspections. Risk-based sampling focuses inspection and regulatory controls on the highest risk pathways, allowing for expedited trade in low-risk commodities (see **Objective 2017-R-4.1**).

Early and systematic detection of pests and diseases is important to limit e.g. crop losses caused by pests and to prevent further expansion of outbreaks, thus facilitating containment or eradication campaigns. Satellites, piloted aircraft and drones can provide precise maps of the Earth's surface and reach locations that are difficult to survey. Recent advances in computer-assisted analysis of images facilitates data analysis and evaluation, reduces costs and eliminates the subjective judgement of a human operator. Such an analysis could be applied for border inspections (consignments) and for general or specific surveillance activities (at places of production, in forests or at outbreak sites).
Spectroscopic (multispectral and hyperspectral) remote sensing approaches (e.g. infrared spectroscopy) are examples of promising technologies that can be deployed to identify biotic (and abiotic) stresses in plants before they become visible to the eye (early warning). Satellites and drones are already used in a number of countries worldwide (e.g. Australia, the United States of America). In Europe, a few projects exploit piloted aircraft/drone images for surveillance for pine wood nematode (*Bursaphelenchus xylophilus*) and the *Flavescence dorée*, but generally practical implementation is lacking in the EPPO region.
International collaboration will support transfer of skills and knowledge; research activities will explore how the technologies could be applied in the field, their costs and identify the regulatory barriers that prevent their application (see **Objective 2017-R-4.2**).

Volatile organic compounds (VOC) play diverse and critical roles in the organism-environment interaction. Plants use volatile metabolites for communication and regulation of various physiological processes; in a similar fashion, it has been demonstrated in more recent years that micro-organisms use VOC in antagonism, mutualism, intra- and interspecies interaction (links to Objective 2017-R-1.1). Volatile sensing technology can be used in plant health to identify stressed plants or microbial communities, providing an early alert (before symptoms become visible). Hundreds of volatiles have been identified so far, whose composition and profiles are linked to the plant, the microbe, their metabolic status, their combination, etc. Research is needed to explore the applicability of the technology to general and specific surveillance activities and for disease management (see **Objective 2017-R-4.3**).

Deep sequencing strongly supports metagenomic studies of microbial communities in any environmental niche (links to Objective 2017-R-1.1), without the need to isolate or culture the community members. The composition of the communities in plants and soil, water and air as specific habitats, should be explored to understand their potential to transport and act as reservoirs for plant pests (links to Objective 2017-R-2.1; Objective 2017-R-2.2). Water and soil monitoring programmes exist and synergies for transfer of knowledge and to develop/adapt protocols and methods for direct (links to Objective 2017-R-6.1) analysis of air, water, soil and plant tissues should be explored (see **Objective 2017-R-4.4**).

Objective 2017-R-4.1: to validate risk-based sampling methodologies for phytosanitary inspections.

Objective 2017-R-4.2: to explore the use of remote sensing technologies to support surveillance and detection activities

Objective 2017-R-4.3: to test and validate the use of volatile organic compounds for early detection and pest management

Objective 2017-R-4.4: to test and validate the use of environmental DNA (eDNA) analysis in inspection and surveillance activities

Objectives of this priority have been endorsed by: Department of Agriculture and Water Resources (AU); Ministry of Agriculture and Forestry, Environment and Water Management (AT); Federal Public Service Health, Food Chain Safety and Environment (BE); Institute for Agricultural and Fisheries Research (BE); Walloon Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Canadian Food Inspection Agency (CA); Federal Office for Agriculture (CH); Ministry of Agriculture, Rural Development and Environment (CY); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); Federal Ministry of Food and Agriculture (DE); Ministry of Agriculture and Forestry (FI); French Agency for Food, Environmental and Occupational Health & Safety (FR); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Benaki Phytopathological Institute (GR); Ministry of Rural Development and Food (GR); Department of Agriculture, Food and the Marine (IE); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry policies (IT); International Center for Advanced Mediterranean Agronomic Studies (Int); Ministry of Agriculture of the Republic of Lithuania (LT); Ministry of Agriculture (LV); National Sanitary Service, Food Safety and Quality (MX); Norwegian Food Safety Authority (NO); The State Plant Health and Seed Inspection Service (PL); Direction-General for Food and Animal Health (PT); Ministry of Agriculture, Forestry and Food (SI); National Institute for Agricultural Research and Food Technology (ES); State Service of Ukraine on Food Safety and Consumer Protection (UA); Department of Agriculture, Animal and Plant Health Inspection Service (US).

Priority 5: Find your enemy - new diagnostic technologies in plant health

Molecular techniques (DNA- or protein-based) have become indispensable tools for the diagnosis of pests. As more sensitive tests are being developed and validated, the limits of detection decrease and the probability that an infected sample is detected at low levels of pathogen concentrations increases. The biological significance of such diagnosis should be studied by linking the results to biological units, associating identified organisms to pathogenicity, and demonstrating the minimum level of (communities of) pathogens necessary to develop a disease in a host (links to Objective 2017-R-1.1; Objective 2017-R-2.2). Such scientific evidence will strengthen diagnostic activities and justify phytosanitary measures (see **Objective 2017-R-5.1**). The private sector (e.g. seed industry, diagnostic industry) should be involved in relevant research activities and in the implementation of results (links to Objective 2017-C-2.1). By developing detection methods for quarantine plant pests based on innovative chemical, acoustic, remote imaging and pest trapping technology, the Q-Detect European project has produced useful knowledge and outputs. Collaboration between experts in the field of microbial ecology, microbiology, population biology, system biology and molecular biology should be pursued (links to Objective 2017-C-1.1). To fully exploit the potential of these molecular techniques, solutions for DNA extraction (from large-volumes of matrices such as soil or plant products) that do not affect the diagnostic sensitivity should be developed and validated (see **Objective 2017-R-5.2)**

Compared to other molecular diagnostic techniques that require prior knowledge of the pathogen(s) to test, Next Generation Sequencing (NGS) allows rapid identification without *a priori* knowledge. Moreover, in case of multiple infections, existing molecular methods do not perform well, while NGS can provide precious metagenomics data (see **Objective 2017-R-5.3**). NGS has thus the potential to become a generic tool for plant health diagnosis and at the same time to generate more data on pest diversity (genomics, population biology, epidemiology, etc.) (links to Objective 2017-R-1.1). Currently, the technology is tightly bound to the laboratory and research is needed to demonstrate the applicability of NGS to plant health diagnostics, to develop standardised methods for sampling, nucleic acid preparation and library preparation that are cheap, reliable and applicable to a wide range of plant products. The technology will support phylogenetic studies (taxonomy) as they will help the identification and characterisation of emerging or re-emerging pests (links to Objective 2017-R-5.1, Objective 2017-R-6.1, Objective 2017-I-2.2; Objective 2017-I-2.4). Next Generation Sequencing (e.g. whole genome sequencing, metagenomics, deep sequencing, typing by sequencing) has great potential to track and trace novel pathogens or novel outbreaks and thereby to support risk management decisions (see **Objective 2017-R-5.4**).

Objective 2017-R-5.1: to understand the biological significance of a positive molecular diagnosis

Objective 2017-R-5.2: to develop and validate high-throughput DNA extraction methods

Objective 2017-R-5.3: to understand mixed infections through metagenomic analysis

Objective 2017-R-5.4: to test and validate the use NGS (e.g. whole genome sequencing, metagenomics, deep sequencing, typing by sequencing) for routine diagnostics

Objectives of this priority have been endorsed by: Department of Agriculture and Water Resources (AU); Ministry of Agriculture and Forestry, Environment and Water Management (AT); Federal Public Service Health, Food Chain Safety and Environment (BE); Walloon Agricultural Research Center (BE); Institute for Agricultural and Fisheries Research (BE); Bulgarian Food Safety Agency (BG); Canadian Food Inspection Agency (CA); Federal Office for Agriculture (CH); Ministry of Agriculture, Rural Development and Environment (CY); Central Institute for Supervising and Testing in Agriculture (CZ); Ministry of Agriculture (CZ); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); Federal Ministry of Food and Agriculture (DE); Ministry of Agriculture and Forestry (FI); French Agency for Food, Environmental and Occupational Health & Safety (FR); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Benaki Phytopathological Institute (GR); Department of Agriculture, Food and the Marine (IE); Ministry of Agriculture, Plant Biosecurity, Plant Protection and Inspection Services (IL); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); International Center for Advanced Mediterranean Agronomic Studies (Int); Ministry of Agriculture of the Republic of Lithuania (LT); Ministry of Agriculture (LV); National Sanitary Service, Food Safety and Quality (MX); Ministry of Economic Affairs (NL); Netherlands Food and Consumer Products Safety Authority (NL); The State Plant Health and Seed Inspection Service (PL); Direction-General for Food and Animal Health (PT); Ministry of Agriculture, Forestry and Food (SI); National Institute for Agricultural Research and Food Technology (ES); Department of Agriculture, Animal and Plant Health Inspection Service (US).

Priority 6: Find your enemy - on site detection and identification of diseases and pests

Pest diagnosis is performed by official laboratories upon request of NPPOs, growers or traders, in samples that inspectors have collected *in situ* (a consignment, a place of production, an outbreak area, a buffer zone, etc.). Resources allocated to official laboratories have decreased over time, while trade in plants and plant products, and consequently the material to be tested, have increased steadily. In order to accelerate diagnosis (especially in the case of perishable goods) and to relieve pressure on laboratories, harmonised sampling methods and on site detection and identification tests, that are both high throughput and scalable at contained costs should be developed and validated for this specific application. Where appropriate, these tests will be performed by inspectors (who are not diagnosticians), thus the technology should be easy to use, require minimal manipulation of the sample and be robust (in terms of reliability). Some promising technologies can be Loop-mediated isothermal amplification (LAMP), lateral flow devices and Next Generation Sequencing (see **Objective 2017-R-6.1**). Links between the activities in the field and in the laboratory should be strengthened (links to Objective 2017-C-2.1).

Objective 2017-R-6.1: to test and validate methods for *in situ* detection and identification of pests

The objective of this priority has been endorsed by: Department of Agriculture and Water Resources (AU); Ministry of Agriculture and Forestry, Environment and Water Management (AT); Federal Public Service Health, Food Chain Safety and Environment (BE); Walloon

Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Canadian Food Inspection Agency (CA); Federal Office for Agriculture (CH); Ministry of Agriculture, Rural Development and Environment (CY); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); Federal Ministry of Food and Agriculture (DE); French Agency for Food, Environmental and Occupational Health & Safety (FR); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Ministry of Rural Development and Food (GR); Benaki Phytopathological Institute (GR); Department of Agriculture, Food and the Marine (IE); Ministry of Agriculture, Plant Biosecurity, Plant Protection and Inspection Services (IL); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); International Center for Advanced Mediterranean Agronomic Studies (Int); Ministry of Agriculture (LV); The State Plant Health and Seed Inspection Service (PL); Direction-General for Food and Animal Health (PT); Ministry of Agriculture, Forestry and Food (SI); National Institute for Agricultural Research and Food Technology (ES); State Service of Ukraine on Food Safety and Consumer Protection (UA).

Priority 7: Deal with the enemy - phytosanitary measures

Phytosanitary measures refer to '*any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests*' (ISPM No. 5). Measures such as risk analysis (e.g. in agricultural chains) and strategies for early detection contribute to a safer trade by preventing the introduction of (new) harmful organisms. Traceability (origin, trace-back, trace-forward) of plants and plant products has emerged as a valuable tool for risk mitigation. Phytosanitary treatments that kill, inactivate, remove, devitalise or render infertile pests are used to prevent introduction and spread of regulated pests. Several measures are supported by extensive research data, others rely on historical evidence supporting their efficacy and the new ones are missing a thorough analysis and validation. The cost-benefit ratio and the economic impact of measures as well as their social acceptability should be assessed to facilitate their implementation. A number of countries, such as Canada and the United Kingdom already have socio-economic units within their national agencies (links to Objective 2017-C-1.1).

Following to the ban of some chemical molecules used to control pests, alternative options have been developed in recent years (controlled atmosphere, ozone, phosphine, sulfuryl fluoride, etc.) but data on efficacy are not always available for an adequate range of commodities and conditions. There is a need for treatments applicable in international trade that have been proven effective in killing, inactivating or removing pests or that render pests infertile, without being phytotoxic or having other adverse effects (see **Objective 2017-R-7.1**).

The same problem applies to intervention strategies at the place of production. Withdrawal of active substances for pest control and increased pest-resistance (links to Objective 2017-R-7.3) have pushed users to look for (cost-)effective, sustainable and environmentally friendly substitutes and to combine conventional approaches with novel intervention strategies and integrated pest management (IPM), including biological control. Detection of biological control agents needs to be in place in order to distinguish them from pathogenic strains (links to Objective 2017-R-5.4). Different physical treatments (e.g. cavitation, plasma, filtration) should be explored alone or in combination with chemicals which could be used in reduced concentrations. Interdisciplinary approaches (modelling, surveillance) (links to Objective 2017-R-3.2; Objective 2017-C-1.1) and synergies with other national and international research funders and initiatives (links Objective 2017-C-3.1) will contribute to reaching the objective (see **Objective 2017-R-7.2**).

Pathogen resistance to pesticides for pest control is widespread. Resistance builds up through the survival and spread of initially rare mutants, during exposure to the treatment. Resistance mechanisms vary but mainly involve modification of the primary site of action of the pesticide within the pest/pathogen. Monitoring is vital to determine whether resistance is the cause in cases of lack of disease control and to check whether resistance management strategies are working. The main resistance management strategies currently recommended are: to avoid repetitive and sole use of a pesticide; to mix or alternate with an appropriate partner pesticide; to limit the number of treatments; to avoid incorrect use (e.g. dose, timing of application); and to integrate with non-chemical methods. However, some recommendations are still based largely on theory, and further experimental data are needed on the underlying genetic and epidemiological behaviour of resistant forms (links to Objective 2017-R-1.1), and on effects of different strategies (see **Objective 2017-R-7.3**).

Objective 2017-R-7.1: to validate cost-effective and socially acceptable phytosanitary measures for consignments (pre-border and at border)

Objective 2017-R-7.2: to validate cost-effective and socially acceptable phytosanitary measures at the place of production (inland) for plants, plant products, water and soil

Objective 2017-R-7.3: to identify and validate strategies for control of pests resistant to pesticides and understand the genetics and epidemiological behaviour of resistant forms

Objectives of this priority have been endorsed by: Department of Agriculture and Water Resources (AU); Ministry of Agriculture and Forestry, Environment and Water Management (AT); State Phytosanitary Control Service at the Ministry of Agriculture Republic of Azerbaijan (AZ); Walloon Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Federal Office for Agriculture (CH); Ministry of Agriculture, Rural Development and Environment (CY); Central Institute for Supervising and Testing in Agriculture (CZ); Ministry of Agriculture (CZ); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Federal Ministry of Food and Agriculture (DE); Ministry of Agriculture National Service of Food Safety, Veterinary and Plant Protection (GE); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Benaki Phytopathological Institute (GR); Ministry of Rural Development and Food (GR); Department of Agriculture, Food and the Marine (IE); Ministry of Agriculture, Plant Biosecurity, Plant Protection and Inspection Services (IL); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); Ministry of Agriculture (LV); National Sanitary Service, Food Safety and Quality (MX); The State Plant Health and Seed Inspection Service (PL); Direction-General for Food and Animal Health (PT); Ministry of Agriculture, Forestry and Food (SI); National Institute for Agricultural Research and Food Technology (ES); Department of Agriculture, Animal and Plant Health Inspection Service (US).

Important pests

Regulations or recommendations for regulations by countries or regions target a large number of pests. It is unlikely that research on all relevant pests can be accomplished within the timing covered by this strategic research agenda. Prioritization is thus needed to allocate resources and to focus research efforts. This issue was raised, for example, during the review of the EU Plant Health Regime, when the proposal was made to substantially reduce the list of regulated pests in order to improve focus. Some countries have developed systems specifically to prioritise efforts across all known potential threats such as the UK Plant Health Risk Register. EPPO has developed a prioritisation process for invasive alien plants but does not have an equivalent system for plant pests. NAPPO has also prioritised weeds. Both RPPOs have noted the difficulty of achieving agreement on priorities across very diverse regions. More quantitative approaches have also been explored for prioritising effort between pests and between different aspects of risk mitigation: exclusion, detection and eradication. However, there are currently no agreed international approaches on how national priority lists can be produced, nor on whether it is possible to envisage meaningful priority lists on a regional or global scale. The transnational funding procedure developed by the Euphresco network can address these limitations. Each year, organisations have the possibility to share the national research priorities with the members of the network. Within a country, information is collected via national workshops and discussions involving research funders and research experts. Those research priorities (also in terms of pests) that receive transnational support will be funded through Euphresco. Along this continuous process that give to countries the possibility to raise the profile of pests which are important for them, a review of the projects that were funded by Euphresco network members in recent years (2015 and 2016) will be undertaken that will allow to identify the most important pests that should be the focus of medium-term action plans. The analysis of priorities identified by different *fora* and for different purposes (e.g. the EPPO Alert List) will help complementing, when relevant, the abovementioned approaches.

Research infrastructures (I)

The term 'research infrastructure' refers to facilities, resources or services that are needed by the research community to conduct research in all scientific and technological fields. It is not in the scope of Euphresco to fund the development of research infrastructures, but Network members can support activities and expertise that benefit from them while contributing to their maintenance. Two priorities have been identified in this Strategic Research Agenda, but Euphresco will aim at complementing existing activities when these are relevant to the plant health community.

Priority 1: Collections

As funding has been scarce on projects concerning fundamental taxonomic research or the maintenance and accessibility of collections and archives, expertise in these areas is declining. As a consequence, relevant collections cannot be managed optimally and maintained (i.e. indexing, updating) properly. Improvement of expertise should be one of the criteria for the prioritisation of research topics (see **Objective 2017-I-1.1)** Collections are often not available to scientists outside the organisation hosting them. The EU-funded project Q-collect inventoried a significant number of collections of plant pests in Europe and showed their main weaknesses such as the limited information on collections' holdings available online, poor sharing of material between collections to avoid loss of biological material and the variable quality systems in place. Availability of well-defined biological material from reliable, curated collections is essential for the development and validation of diagnostic tests and is the cornerstone of taxonomy (see **Objective 2017-I-1.2**). The research community does not need reference collections in every country or at every laboratory, but needs access to these collections. The development of a long-term sustainable online platform to access collections will increase their visibility and facilitate accessibility to biological material, providing a rationalised framework to optimise the use of funds (to collections) that are not secured. A network of collections should be established in order to share the responsibility for maintaining reference material and also to plan replication for back-ups whenever necessary (see **Objective 2017-I-1.3**).

Objective 2017-I-1.1: to support knowledge exchange for efficient management and maintenance of collections

Objective 2017-I-1.2: to improve access to collections of phytosanitary importance

Objective 2017-I-1.3: to build a network of collections that fulfil minimum quality standards

Objectives of this priority have been endorsed by: Department of Agriculture and Water Resources (AU); Ministry of Agriculture and Forestry, Environment and Water Management (AT); State Phytosanitary Control Service at the Ministry of Agriculture Republic of Azerbaijan (AZ); Walloon Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Federal Office for Agriculture (CH); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); French Agency for Food, Environmental and Occupational Health & Safety (FR); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Benaki Phytopathological Institute

(GR); Ministry of Rural Development and Food (GR); Department of Agriculture, Food and the Marine (IE); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); Ministry of Agriculture (LV); National Sanitary Service, Food Safety and Quality (MX); Ministry of Economic Affairs (NL); Netherlands Food and Consumer Products Safety Authority (NL); The State Plant Health and Seed Inspection Service (PL); Direction-General for Food and Animal Health (PT); Ministry of Agriculture, Forestry and Food (SI); National Institute for Agricultural Research and Food Technology (ES); Department of Agriculture, Animal and Plant Health Inspection Service (US).

Priority 2: Information technology to support plant health activities

Publication of theories has been at the foundation of the scientific practice since the first scientific journals were established. Alongside the publication of results, openness of data has received increasing attention in recent years. New ways to collect, store, manipulate and transmit information have been developed, tools exist for the indexing and research of data in a few milliseconds and the amount of (scientific) data produced in the world is exploding. The use and re-use of data nurtures classic and novel (i.e. modelling, link to Objective 2017-R-3.2) research investigations and can help plant health activities. Data on partial or whole genome sequences can be used to identify micro-organisms and to track and trace particular strains. Research policy should favour the sharing of high quality data especially when data-sets are unique, expensive to produce and have a high potential for re-use (see **Objective 2017-I-2.1**). Databases play an important role in the approach, however, an essential component is how the results are produced locally. Forensic investigation could provide the methodologies (tools for sampling, shipping, storage, microbial identification, epidemiological modelling, bioinformatics, etc.) to address the different questions and have higher resolution than those normally used in plant pathogen diagnosis (links to Objective 2017-C-1.1).

Public data repositories exist for many disciplines. The plant health sector could benefit from initiatives such as the Global Microbial Identifier (GMI) and existing infrastructures, such as Q-bank and the EPPO Global database for the optimal exploitation of genomic information for the detection and identification of plant pests. In other cases (e.g. proteomics), only proprietary databases exist for the interpretation of MALDI-TOF spectra, which limits the application of this technology for phytosanitary applications. Before more research is funded to evaluate the applicability of MALDI-TOF mass spectrometry for rapid microbial identification, databases should be made available (see **Objective 2017-I-2.2**).

Risk assessment is complicated by the unavailability (or lack) of metadata on the exact host(s) distribution and the cultural practices and control measures applied in the risk assessment area for the management of other pests affecting the host(s). For the EPPO region, data on the distribution of some crops/forest tree species may be available at the EU Joint Research Centre (JRC). However, this data does not cover all the economically important crops for the EPPO region and no data exists on the cultural practices/control measures applied by the various countries (see **Objective 2017-I-2.3**).

Tools are required to enable rapid, precise and specifically targeted interventions when a phytosanitary issue is identified. Information technology provides numerous opportunities to support plant protection services. Pest-dedicated applications for mobile devices ‘Apps’ and databases should be developed to guide precise interventions, with particular attention to field data acquisition (e.g. geo-localization and sampling) and to facilitate identification (links to Objective 2017-R-6.1; Objective 2017-C-1.1). These tools will facilitate more accurate and systematic monitoring of pest and pathogens, including invasive threats, harmonizing data collection procedures and subsequent analyses (links to Objective 2017-I-2.1). Field data acquired by dedicated ‘Apps’ could provide the basis for statistical and epidemiological studies (see **Objective 2017-I-2.4**).

Objective 2017-I-2.1: to support data exchange, data use and re-use for the benefit of plant health research activities

Objective 2017-I-2.2: to contribute to databases for plant pests identification and diagnostics

Objective 2017-I-2.3: to develop databases on (i) distribution of economically important crops, and (ii) cultural practices/control measures applied by the various countries

Objective 2017-I-2.4: to use information technology in pest/pathogen surveillance programmes

Objectives of this priority have been endorsed by: Department of Agriculture and Water Resources (AU); Ministry of Agriculture and Forestry, Environment and Water Management (AT); Institute for Agricultural and Fisheries Research (BE); Walloon Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Canadian Food Inspection Agency (CA); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); French Agency for Food, Environmental and Occupational Health & Safety (FR); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Benaki Phytopathological Institute (GR); Ministry of Rural Development and Food (GR); Department of Agriculture, Food and the Marine (IE); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); International Center for Advanced Mediterranean Agronomic Studies (Int); Ministry of Agriculture (LV); Ministry of Economic Affairs (NL); Netherlands Food and Consumer Products Safety Authority (NL); The State Plant Health and Seed Inspection Service (PL); Direction-General for Food and Animal Health (PT); National Institute for Agricultural Research and Food Technology (ES).

Cooperation (C)

Priority 1: Disciplines

Interdisciplinary approaches are needed to address the plant health challenges and to deliver stratified knowledge to nurture new research activities and to support decision making on appropriate phytosanitary measures.

Computational biology and mathematics should support classical expertise in plant health by developing models to understand the spread, establishment and impact of pests in order to prioritize the risks (links to Objective 2017-R-1.1; Objective 2017-R-2.1; Objective 2017-R-3.2; Objective 2017-R-4.1).
Bioinformatic pipelines are necessary to allow reliable and quick analysis of a large amount of data, such as remote sensing maps or whole genome sequences (links to Objective 2017-R-4.2; Objective 2017-R-4.4; Objective 2017-R-5.2; Objective 2017-R-5.3; Objective 2017-R-5.4). With the increasing amount of data generated worldwide and its availability for use and re-use in different contexts, the development of unique entry points will facilitate the visibility, accessibility and exploitation of the information.
Computing skills should support the development of relevant tools and IT infrastructures (i.e. databases) (links to Objective 2017-I-1.2; Objective 2017-I-1.3; Objective 2017-I-2.1; Objective 2017-I-2.2; Objective 2017-I-2.3; Objective 2017-I-2.43).
Economics, psychology, sociology will provide complementary knowledge to integrate plant health problems in the society by taking account of human factors in the assessment and perception of risks and acceptance of management options (links to Objective 2017-R-3.1; Objective 2017-R-7.1; Objective 2017-R-7.2); medical physics (e.g. imaging), metrology and forensic science (e.g. its standard operating procedures, SOP) could provide tools and approaches (see **Objective 2017-C-1.1**).

Objective 2017-C-1.1: to address plant health challenges through integrative approaches and support collaboration among disciplines

The objective of this priority has been endorsed by: Department of Agriculture and Water Resources (AU); Ministry of Agriculture and Forestry, Environment and Water Management (AT); Walloon Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Federal Office for Agriculture (CH); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); Ministry of Agriculture and Forestry (FI); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Ministry of Rural Development and Food (GR); Department of Agriculture, Food and the Marine (IE); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); Ministry of Agriculture (LV); The State Plant Health and Seed Inspection Service (PL); Direction-General for Food and Animal Health (PT); National Institute for Agricultural Research and Food Technology (ES).

Priority 2: Players

National plant protection organisations and the networks of inspectors and diagnosticians in each country provide a front-line service to guarantee plant quality and protection. Increased cooperation to support knowledge exchange and capacity building should be pursued to enhance efficient delivery of activities in the field and in the laboratory (links to Objective 2017-R-6-1).

It is however clear that governments alone cannot tackle threats to plant health and other stakeholders, including industry, non-government organisations, land-owners and the public, have an important role to play to protect the health of plants. For example, inspectorates and border force officers are in a unique position to facilitate trade while safeguarding interests linked to plant health through enhanced and systematic sharing of risk information. Citizen science has proved to be successful in involving the public in participative and collaborative activities where the public work alongside scientists to contribute evidence, ideas, questions and methods to research projects; volunteers have successfully contributed to monitoring campaigns (e.g. the Observatree project in the United Kingdom) thus increasing surveillance capacity and reporting of plant pests. Educational kits, awareness campaigns and communication plans should be developed to improve communication in plant health and raise the profile of the best plant biosecurity practice with relevant stakeholders. Building stronger links with growers and advisory services may facilitate the uptake of phytosanitary measures. Examples of an active involvement of farmers already exist, such as the plantwise initiative (links to Objective 2017-R-4.4; Objective 2017-R-7.2; Objective 2017-R-7.3). Public bodies at the (inter)national, regional and local levels, domestic and international NGOs and public societies should engage in international activities to improve plant health, facilitate the sharing of information and best practice and work pro-actively with importers and exporters to deliver better outcomes. Knowledge exchange should be promoted to increase research impact, e.g. through the creation of multi-partner research platforms to involve a range of stakeholders such as the International Seed Federation (ISF), the International Seed Testing Association (ISTA), the International Seed Health Initiative (ISHI) and the European Seed Association (ESA) in research activities (see **Objective 2017-C-2.1**).

Objective 2017-C-2.1: to address plant health challenges through whole-chain, multi-actor approaches

The objective of this priority has been endorsed by: Ministry of Agriculture and Forestry, Environment and Water Management (AT); Federal Public Service Health, Food Chain Safety and Environment (BE); Walloon Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); Ministry of Agriculture and Forestry (FI); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Benaki Phytopathological Institute (GR); Ministry of Rural Development and Food (GR); Department of Agriculture, Food and the Marine (IE); Ministry of Agriculture, Plant Biosecurity, Plant Protection and Inspection Services (IL); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); Ministry of Agriculture (LV); The State Plant Health and Seed Inspection Service (PL); Direction-General for Food and Animal Health (PT); Ministry of Agriculture, Forestry and

Food (SI); National Institute for Agricultural Research and Food Technology (ES); Department of Agriculture, Animal and Plant Health Inspection Service (US).

Priority 3: Initiatives

If openness and internationalisation of research activities are gaining pace throughout the world, the R&D panorama is still composed of regional, national and grassroots level initiatives, with an inherent fragmentation of efforts as the activities are programmed, financed, monitored and evaluated by different players, with little collaboration and coordination. Exchange of information remains the easier and faster solution to support collaboration and rationalise the efforts. Collaboration and concerted initiatives with the following organisations will be useful for the successful implementation of research activities (be those mentioned or not in this Strategic Research Agenda): FAO, regional plant protection organisations (e.g. EPPO and NAPPO), the EU DG Agriculture et Rural Development (Agriculture), DG Research and Innovation (R&I), DG Health and Food Safety (Santé), the European Food Safety Authority (EFSA), the International Association for the Plant Protection Sciences (IAPPS), the European Plant Science Organisation (EPSO), relevant ERA-Net and initiatives (such as Core-Organic, SUMFOREST and the EU Minor Uses Coordination Facility) and national plant protection organisations. Plant health research could also benefit from knowledge and infrastructures developed in the human and animal health fields. Activities such as the Global Microbial Initiative (links to Objective 2017-I-2.2), ELIXIR and those undertaken by the STAR-IDAZ network should be followed and synergies found when possible (see **Objective 2017-C-3.1**).

Objective 2017-C-3.1: to favour knowledge exchange and support common initiatives with relevant players

The objective of this priority has been endorsed by: Ministry of Agriculture and Forestry, Environment and Water Management (AT); Federal Public Service Health, Food Chain Safety and Environment (BE); Walloon Agricultural Research Center (BE); Bulgarian Food Safety Agency (BG); Federal Office for Agriculture (CH); Ministry of Food, Agriculture and Fisheries, Danish AgriFish Agency (DK); Ministry of Rural Affairs (EE); Ministry of Agriculture and Forestry (FI); French Agency for Food, Environmental and Occupational Health & Safety (FR); Department for Environment, Food and Rural Affairs (GB); Science and Advice for Scottish Agriculture (GB); Benaki Phytopathological Institute (GR); Ministry of Rural Development and Food (GR); Department of Agriculture, Food and the Marine (IE); Council for Agricultural Research and Agricultural Economics Analysis (IT); Ministry of Agricultural Food and Forestry Policies (IT); International Center for Advanced Mediterranean Agronomic Studies (Int); Ministry of Agriculture (LV); Netherlands Food and Consumer Products Safety Authority (NL); The State Plant Health and Seed Inspection Service (PL); Direction-General for Food and Animal Health (PT); National Institute for Agricultural Research and Food Technology (ES).