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COMPENDIUM ON THE PLANT HEALTH RESEARCH PRIORITIES FOR THE MEDITERRANEAN REGION

INTERNATIONAL YEAR OF
PLANT HEALTH
2020

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Euphresco

Compendium on the plant health research priorities for the Mediterranean region

A preliminary study coordinated by
the International Centre for Advanced
Mediterranean Agronomic Studies
and
the Euphresco network for phytosanitary
research coordination and funding

Contents

Introduction

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The Mediterranean region is home to about 25000 plant species, of which 13000 are endemic (not found anywhere else on Earth) and has been recognised by Myers[1] and collaborators as a biodiversity hotspot that is suffering an exceptional loss of habitat.

Mediterranean agriculture, forests and other environments are seriously threatened by numerous quarantine and emerging pests[2], and their negative impacts are expected to increase due to the acceleration of global trade and to climate change that respectively favour the movement of these organisms over long distances and facilitate their adaptation to new environments.

In the face of these challenges, the Mediterranean region is particularly vulnerable due to the weakness of national quarantine systems, limited expertise and phytosanitary infrastructures, and not least the lack of funds for research activities in support of statutory plant health.

The strengthening of research in the field of plant health is one of the main challenges that countries in the Mediterranean region have to address. The diversity of priorities both in terms of pests and in terms of infrastructures and skills has weaken the impact of national efforts, but plant health challenges require rethinking of the organization of research activities in all countries and their coordination in order to increase efficiency and impact.

Coordination at Mediterranean level will reduce the fragmentation of actions; it will promote convergence of national programmes; it will allow optimization of scarce funding and to build critical mass.
There is a need to increase the excellence and relevance of research, to improve and strengthen cooperation within the region by sharing objectives and priorities. A sustainable protection strategy is more essential than ever in order to protect the whole region from phytosanitary threats and biodiversity erosion.

In this context, Euphresco and CIHEAM Bari, two international players actively involved in different fields of plant health and plant protection, aim to improve the coordination of research efforts (from research funding to research activities) on plant health and plant protection in the Mediterranean area and to enhance cooperation of stakeholders within the area.

The Euphresco network for phytosanitary research coordination and funding is an international network of research programme owners, programme managers, policy makers, regulators and research and educational organizations from more than 50 countries in 5 continents. 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 optimise limited funds; c) to better support phytosanitary science capability through such transnational activities and research projects.

The CIHEAM Bari is a Centre for post-graduate training, applied scientific research and planning of partnership actions in the field of research and international cooperation in the Mediterranean region. Plant health is one of the historical pillars of its mission. CIHEAM Bari activities have focused mainly on the development and transfer of advanced detection methods and tools, characterisation and epidemiological studies on the main or new pests (e.g. *Citrus tristeza virus*, *Xylella fastidiosa*) affecting priority crops in this region (e.g. citrus, olive), with a special emphasis on the production and use of certified plant propagating materials. In recent years, CIHEAM Bari has contributed to the development and integration of smart technologies in pest risk analysis, early surveillance and prediction for the implementation of precision Decision Support Systems (DSS).
It has trained many young researchers on different aspects of plant health (specialized short courses, Master's degrees and PhD programs) and has connected scientists through international cooperation programs to strengthen capacity and awareness on plant health, not only in its member countries, but also in those geographically close to this region.

As a first joint action, Euphresco and CIHEAM Bari organised a survey on the research priorities for the Mediterranean basin by collecting views of national experts from the following areas: the Balkan-Mediterranean, Eastern Mediterranean, Maghreb, and Western Mediterranean. The information collected covers: important pests, research priorities, important research infrastructures and research capacity.

The results of this survey are summarised in this Compendium, which also received contributions from experts from other international organizations supporting cooperation in the Mediterranean area: Khaled Makkouk, Ibrahim Jboory and Ahmed Katbeh from the Arab Society for Plant Protection (ASPP), Anne-Sophie Roy from the European and Mediterranean Plant Protection Organization (EPPO), Thaer Yaseen from the Food and Agriculture Organization (FAO), Laura Mugnai, Antonio Logrieco and Giuseppe Surico from the Mediterranean Phytopathological Union (MPU), and Mekki Chouibani from the Near East Plant Protection Organization (NEPPO).

The survey was sent to the national contact points of the organizations that are members of Euphresco (research funders and national plant protection organizations) and to alumni of the CIHEAM Bari.
This approach allowed to combine research and policy views but also field experience and national guidance. As in the case for all surveys, this one has the limitation that it only represents the views of the experts that agreed to participate. While we are aware of these limitations, we also note that the Compendium is one of the rare attempts to provide guidance to plant health research stakeholders in the Mediterranean area.

The Compendium is not an end but a beginning, and it is hoped that the document could firstly set the basis for more coordinated operations of all plant health stakeholders in the Mediterranean region, and in particular research funders and that, as a reference document, could provide a common ground for discussions in order to foster cooperation within the region.
The CIHEAM Bari and Euphresco will continue, with the help of other interested international organisations, to make sure that the document remains relevant over the time, in order to serve research collaboration and coordination for Mediterranean countries.

The United Nations General Assembly declared 2020 the International Year of Plant Health (IYPH) to raise public awareness of how plant health can help end hunger, reduce poverty, protect the environment and promote economic development. The compendium will hopefully contribute to help achieve these objectives, guiding and supporting research in plant health throughout the Mediterranean area in a sustainable and effective way.

[1]Myers N., Mittermeier R.A., Mittermeier C.G., da Fonseca G.A., Kent J. Biodiversity hotspots for conservation priorities. Nature 403(6772): 853-8 (2000).
[2]Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products. A regulated pest is a quarantine pest or a regulated non-quarantine pest (Glossary of phytosanitary terms, ISPM5, 2020)

1. Important pests for the Mediterranean area

Laura Mugnai, Antonio Logrieco and Giuseppe Surico, Mediterranean Phytopathological Union (MPU, Italy)

The Mediterranean area is a crossroad for three different continents, with different climatic conditions, environments, and human cultures.

All this variability is reflected in agricultural cultivation, the related pests and consequently, in the plant health challenges.
Since ecosystems are very fragile and dynamic entities, in which organisms interact with each other and with the environment, any event has the potential to affect all the components of the living and non-living community.

Global trade and climate change have the strongest impact, as they facilitate the movements of pests and their introduction/establishment in new areas, where they can have unacceptable impacts on agriculture, ecosystems, trade and finally the economy.

To avoid damage, phytosanitary measures have been set up to prevent the entry into a new area of a pest not present in that area or to prevent their establishment and spread into other areas.

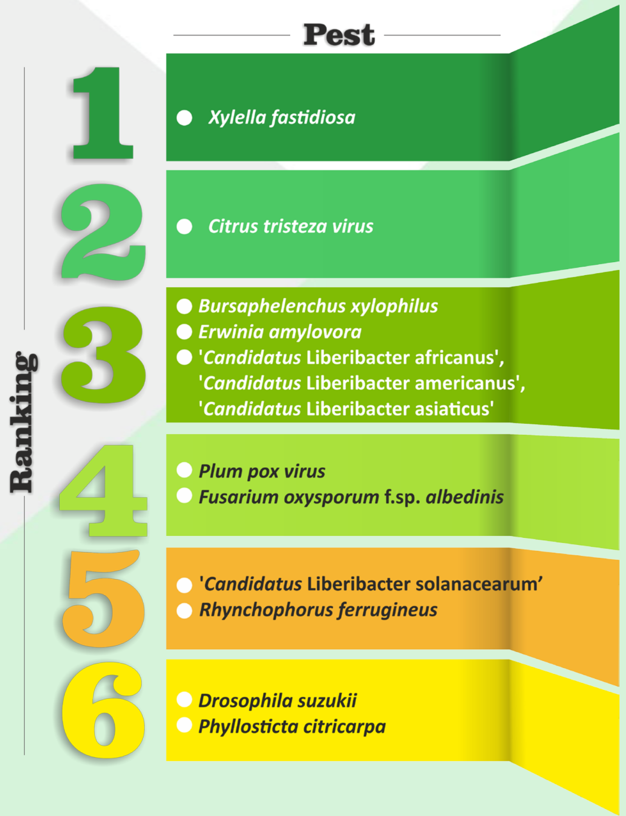
These measures may consist of legal restrictions (regulations) which limit the import of specific plants or plant parts, as well as procedures to eradicate newly introduced pests as soon as possible and to control and contain them to avoid further spread.

The recent introduction into the Mediterranean area of *Xylella fastidiosa* and its devasting effect on olive trees is a clear demonstration of a certain fragility of plant quarantine measures in force in Europe. This may mean the urgent need of some adjustments of the community rules in operation today, for example to improve interventions in the very early stages of the appearance of a new phytosanitary event.

But it also suggests that efforts on common threats should be more coordinated in order to favour capacity building, optimization of the use of resources that support preparedness and actions. Coordination and collaboration will build on the environment created by existing initiatives and societies, such as the Mediterranean Phytopathological Union, which has secured, through its journal Phytopathologia Mediterranea, the spread of scientific information on plant pests occurring in the region for six decades.

A survey was organised to gather the points of view of experts from the region on the pests that are perceived as the most threatening for the Mediterranean region, and for which more research activities should be undertaken.

A ranking was made, based on the information collected during the survey (frequency of citations by the experts consulted), and the most important pests are listed below:



Information on the pests that were identified as the most threatening to the Mediterranean area is presented in the next pages and it is summarized from the EPPO datasheets.

EPPO has a long experience in preparing datasheets on regulated pests. While this compendium was being compiled, EPPO revised existing datasheets and prepared new ones, in case no datasheet was available yet, on the 11 pests.

In 2019 and 2020, together with CIHEAM Bari and the Mediterranean Phytopathological Union, experts were requested to revise or prepare the EPPO datasheets. The EPPO Secretariat warmly thanks all experts for their contribution and active participation.
The EPPO Secretariat published these 11 datasheets in a new, more dynamic format in its online and free-access database 'EPPO Global Database'.

Data on the pest identity, host plants and geographical distribution is now automatically generated by the database and thereby kept up to date.

The information that is shown below has been summarized from the newly prepared EPPO datasheets. Maps are those generated by EPPO. Full datasheets can be downloaded from the EPPO Global Database (www.gd.eppo.int or click on the individual links in each of the summaries below to access them).

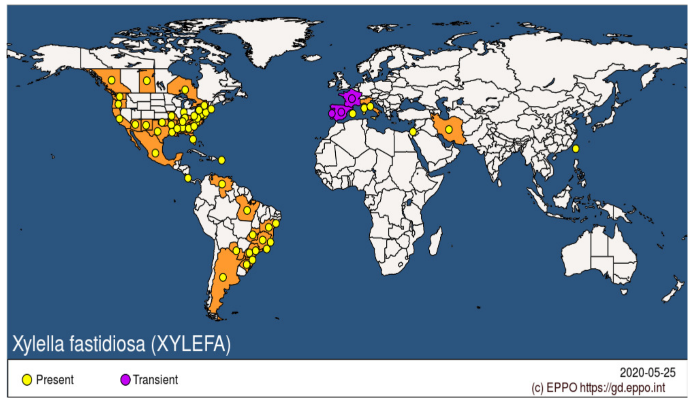
Xylella fastidiosa

Xylella fastidiosa is a bacterium which can cause severe diseases in economically important fruit crops and many other woody plants.

X. fastidiosa is a genetically diverse species that has been associated with a wide range of plant diseases, the most important are: Pierce's disease of grapevine in North America, citrus variegated chlorosis (CVC) in South America, and olive quick decline syndrome (OQDS) in Europe and the Mediterranean region.

Geographical distribution

The outbreak of *X. fastidiosa* in olive trees in Southern Italy and the presence of the bacterium in Mediterranean plant species in the natural and urban landscapes of Italy, France, Spain and Portugal, constituted a major change to its geographical distribution.



Hosts

X. fastidiosa is a polyphagous bacterium that can infect the xylem of a wide range of cultivated and wild host plants. A total of 595 plant species have been reported in the scientific literature as plant hosts of *X. fastidiosa*. The bacterium is known to cause severe direct damage to several major crops including olive, grapevine, almond, coffee, citrus, stone fruits, as well as forest, landscape and ornamental trees.

Economic impact

X. fastidiosa is the causal agent of the olive quick decline syndrome, a devasting disease of olive trees that in 2013 emerged in Apulia (Southern Italy). Since then, the disease has advanced by an average of 2 km a month. As of 2019, it has been estimated that approximately 11 million plants were infected, over an area of about 50 000 ha.

Damage concerned olive trees in production as well as nurseries of olive plants and has been estimated at a total of 1.2 billion EUR. An indirect impact concerned the export from Italy of any species of plants susceptible to *X. fastidiosa*. Finally, the damage caused by *X. fastidiosa* to the landscape of the 'Salento' Peninsula in Apulia and to the Mediterranean cultural heritage associated to olive trees is unquantifiable.

In the USA, *X. fastidiosa* is responsible for the Pierce's disease of grapevine.
In California alone, the value of grapevine losses to Pierce's disease is on average of 56.1 million USD/year. Moreover, since another 48.3 million USD are spent to limit the populations of the vector the bacterium, the estimated cost of Pierce's disease is approximately of 104.4 million USD per year.

The information above is based on the EPPO Datasheet on *X. fastidiosa*, revised in 2020 by G. Surico and G. Marchi from the University of Florence (UNIFI), Firenze, Italy. The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global Database.

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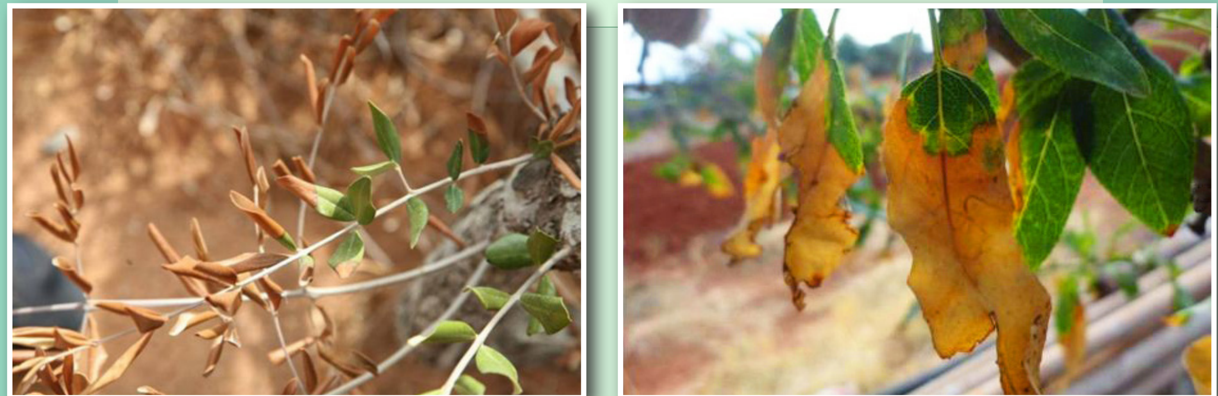
Xylella fastidiosa

Figure 1. Pierce's disease of grapevine cultivar Chardonnay. *Courtesy of A. H. Purcell (UC Berkeley, USA).*

Figure 2. Citrus Variegated Chlorosis on sweet orange. *Courtesy of S. A. Lopes (Fundecitrus, Brazil).*

Figures 3. Olive grove infected by *X. fastidiosa* showing Olive Quick Decline symptoms (left); Quick Decline of ancient olive trees (right). *Courtesy of F. Valentini (CIHEAM Bari, Italy).*



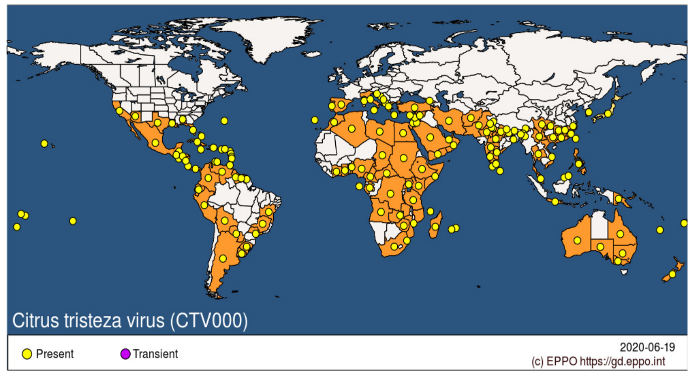
Figures 4. Leaf scorch symptoms caused by *X. fastidiosa* on olive trees (left) and almond (right). *Courtesy of D. Boscia (CNR of Bari, Italy).*

Citrus tristeza virus

Citrus tristeza virus (CTV) is one of the most devastating virus diseases of citrus worldwide.

Geographical distribution

The virus is present in all continents. Around the Mediterranean basin, it is important to prevent the spread of severe strains of *Citrus tristeza virus.*



Hosts

Citrus tristeza virus infects most species and hybrids of the *Citrus genus*, as well as a large number of other Rutaceae. Citrus hosts widely cultivated in the Mediterranean area that can be affected by the virus are: sweet orange (*Citrus sinensis*), sour orange (*C. aurantium*), mandarin (*C. reticulata*), lemon (*C. limon*) and grapefruit (*C. paradisi*).

Economic impact

Within the Euro-Mediterranean region, repeated and severe *Citrus tristeza virus* outbreaks occurred in the 1950s in Spain, where more than 40 million trees were killed.

In the 2000s, outbreaks also took place in Italy and caused the dieback of over 400 000 trees in Apulia and Sicily. *Citrus tristeza virus* is a serious threat for the citrus-growing countries in the Mediterranean basin, where the highly susceptible sour orange rootstock is still extensively used, and where aphid vectors are widely present. Spain, Israel, and recently Italy are the most affected countries in the region.

The information above is based on the EPPO Datasheet on *Citrus tristeza virus*, revised in 2020 by D. Yahiaoui from the Technical Center of Citriculture (CTA), Z. Djedidi, Tunisia. The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global Database.

Citrus tristeza virus

Figure 5. Symptoms of quick decline induced by *Citrus tristeza virus* on sweet orange grafted on sour orange rootstock. *Courtesy of A.M. D'Onghia (CIHEAM Bari, Italy).*

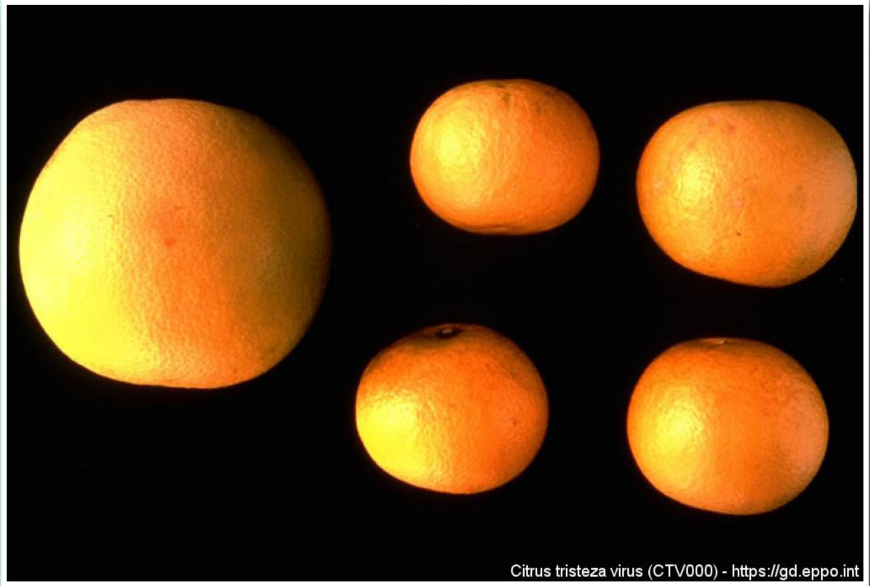
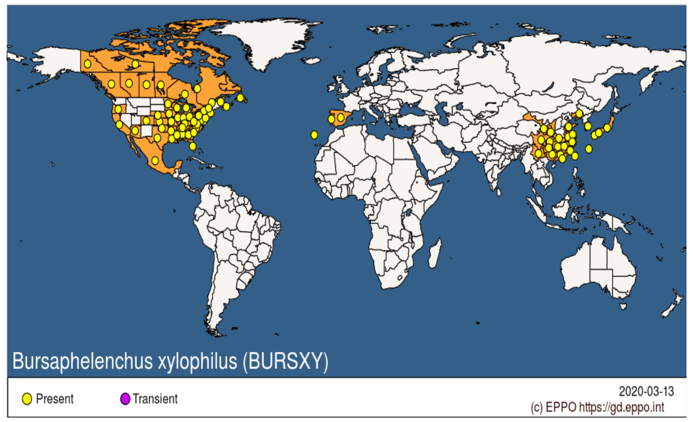


Figure 6. Symptoms of *Citrus tristeza virus* infection on grapefruit. One fruit from a healthy tree (left) and four fruits from an infected tree (right). *Courtesy of L. Navarro (IVIA, Spain).*

Bursaphelenchus xylophilus

Bursaphelenchus xylophilus is a nematode that causes pine wilt disease.

Geographical distribution



It is presumed that *B. xylophilus* originated in North America and was transported from there to the southern Japanese island of Kyushu in infected timber in the beginning of the 20th century. From Japan, *B. xylophilus* has spread to other Asian countries and then, at the end of the 20th century, it was introduced in Europe, in Portugal (mainland and Madeira island) and Spain (isolated outbreaks).

Hosts

B. xylophilus is found mainly on *Pinus* spp. Nevertheless, only a limited number of pine species are considered susceptible to the nematode infection. Many other species have been found to be damaged or killed by the nematode but only under experimental conditions (mainly as seedlings in glasshouses).
Other conifers can also act as hosts (*Abies, Cedrus, Larix, Picea and Pseudotsuga*) but reports of damage are rare.

Economic impact

In the Mediterranean area, *P. nigra and P. pinaster* are the most threatened *Pinus* spp. Predicted losses in wood production in the European Union from the spread and damage from *B. xylophilus* were estimated at 22 billion euros over 22 years, with losses in standing volume in Portugal and Spain greater than 80%.

In China, in a year, tree mortality reached 2.3 million just in a single county with over one million trees killed each year from 1995 to 2006 while in South Korea over one million trees were affected by pine wilt disease in 2005–2006.

The information above is based on the EPPO Datasheet on *B. xylophilus*, revised in 2019 by I. Abrantes and L. Fonseca (University of Coimbra, Portugal) and P. Naves (INIAV, Oeiras, Portugal). The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global Database.

Bursaphelenchus xylophilus

Figure 7. Wilted pine damaged by B. xylophilus. *Courtesy of M. Mota (University of Evora, Portugal).*

Figure 8. Wilting pine trees damaged by B. xylophilus. *Courtesy of M.M. Galvão de Melo and M. Mota (University of Evora, Portugal).*

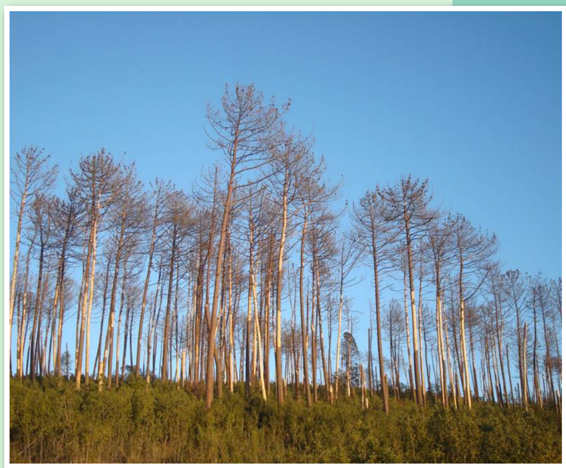


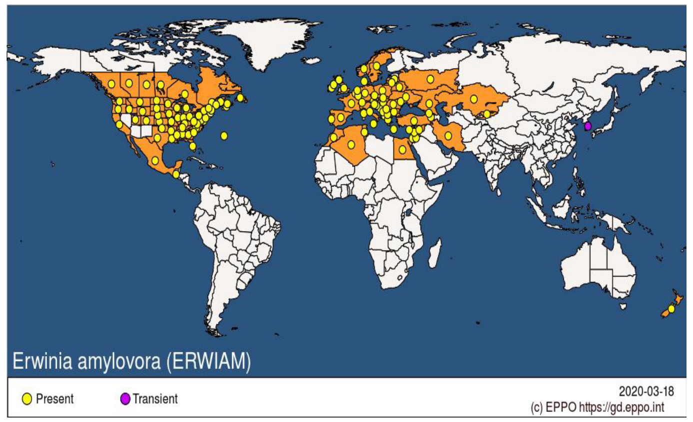
Figure 9. Dead pine trees killed by B. xylophilus. *Courtesy of P. Naves (INIAV, Oeiras, Portugal).*

Erwinia amylovora

Erwinia amylovora, the causal agent of fireblight disease, is one of the most studied bacteria because its high economic impact on pome fruit production.

Geographical distribution

Fireblight was first reported in Europe (England) in 1957. Since then, it rapidly spread through Western Europe and the Middle East. On the African continent, fireblight was declared to be present for the first time in 1964 in Egypt. Currently, this disease has reached many parts of the world.



Hosts

Fireblight, caused by *Erwinia amylovora*, affects plants within the Rosaceae family, and more particularly those in the subfamily Maloideae which includes economically important pome fruit trees, such as apple (*Malus domestica*) and pear (*Pyrus communis*). Wild *Pyrus* species (*P. amygdaliformis, P. syriaca*) play an important role as sources of inoculum in Southern Europe and in the Mediterranean area, because of their abundance in these areas. *Crataegus* (*C. laevigata, C. monogyna*) and ornamentals (*Pyracantha, Cotoneaster, Sorbus*) are important sources of inoculum for apple and pear trees in Europe.

Economic impact

In susceptible hosts the infection spreads so rapidly through the tree that, once infected, trees cannot be saved, even by drastic and immediate surgery, and die within a short time after the first visual signs of infection.

The economic impact is difficult to quantify because it depends on the intensity of the epidemic and a fireblight attack can have repercussions over several years.

In the USA, crop losses and control costs have been estimated to be more than 100 million USD per year.

In Switzerland, where the disease was first observed in 1989, the financial burden of control measures (from quarantine to diagnostics), together with compensation payments for destroyed plants, were estimated to be about 35 million EUR over a 14-year period, from 1989 to 2003.

The information above is based on the EPPO Datasheet on *E. amylovora*, revised in 2020 by S. Laala (ENSA, Alger, Algeria). The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global Database.

Erwinia amylovora

Figure 10. Severe damage caused by *E. amylovora* in a quince orchard cv. Esfahan. *Courtesy of H. Abdollahi (HSRI, AREEO, Karaj, Iran).*

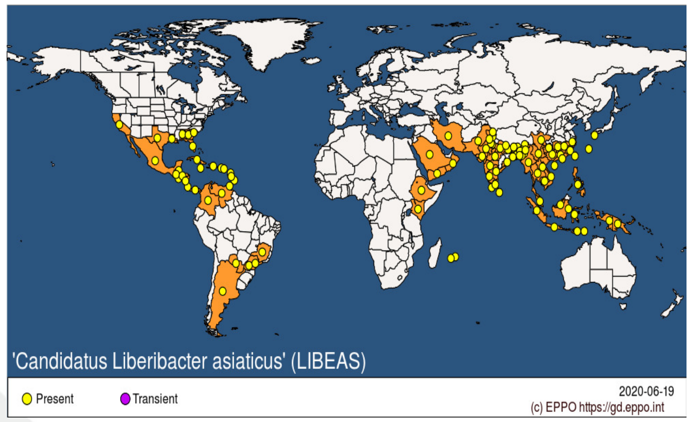
Figure 11. Fields symptoms of fire blight on quince. *Courtesy of E. Osdaghi (Shiraz University, Iran).*

Figures 12. Fire blight of pear: mummified fruits and brown leaves clinging to the stem (left); bacterial exudates from cankers on the trunk (right). *Courtesy of F. Valentini (CIHEAM Bari, Italy).*

'Candidatus Liberibacter africanus', *'Candidatus* Liberibacter americanus' and *'Candidatus* Liberibacter asiaticus' (Huanglongbing)

Huanglongbing (HLB) is one of the most devastating disease of citrus trees. For many years, the possible causes of this disease remained uncertain. The discovery of cell-walled bacteria in affected plants demonstrated that true bacteria were present and three taxonomic entities are currently associated with huanglongbing symptoms: *'Candidatus* Liberibacter africanus', *'Candidatus* Liberibacter americanus' and *'Candidatus* Liberibacter asiaticus'.

Geographical distribution



'Candidatus Liberibacter asiaticus' was probably first observed in Asia in the 18th century when a severe disease of unknown origin called 'citrus dieback' was recorded in the central provinces of India.

A disease causing yellowing and leaf mottle symptoms was reported in Southern China as present since the late 19th century and farmers called it 'Huanglongbing' (yellow shoot disease). For decades, Huanglongbing has been considered limited to Asian and African countries, but in 2004 it was found in Brazil and in 2005 in Florida (USA).

The Mediterranean area and most of the Middle East, Australia, New Zealand, New Caledonia and small Pacific islands are still free from the disease. The map below shows the world distribution of '*Ca.* Liberibacter asiaticus'. Click on the links to view the distributions of *'Ca.* Liberibacter africanus' and *'Ca.* Liberibacter americanus'.

Hosts

The three species of *'Ca.* Liberibacter' infect species of *Citrus* and other genera within the *Rutaceae* family.

There is no available information about differences in host range between *'Ca.* Liberibacter asiaticus' and *'Ca.* Liberibacter africanus'.

Both can multiply and colonize many *Citrus* spp., but the most severe symptoms are found on sweet orange (*C. sinensis*), mandarin (*C. reticulata*) and tangelo (*C. reticulata x C. paradisi*). Somewhat less severe symptoms are found on lemon (*C. limon*), grapefruit (*C. paradisi*), Rangpur lime (*C. limonia*), Palestinian sweet lime (*C. limettioides*), rough lemon (*C. jambhiri*), kumquat (*Fortunella spp.*) and citron (*C. medica*). Symptoms are even weaker on lime (*C. aurantiifolia*) and pummelo (*C. grandis*).

Economic impact

Huanglongbing is currently regarded as one of the most important socio-economic threats to commercial citrus production at global level.

Almost 100 million trees have been affected and destroyed in many countries of South and Southeast Asia, compromising the local citriculture and large areas of citrus cultivation have been abandoned.

In the Americas, the economic impact has also been dramatic. In Brazil, five years after outbreaks were officially declared in 2004, more than 4 million trees were eliminated in attempts to limit the dissemination of *'Ca.* Liberibacter asiaticus and *'Ca.* Liberibacter americanus'.

One year later, the number of symptomatic trees was estimated to be ca. 2 million (ca. 87 %).

In Florida (USA), since the disease was reported in 2005, the costs of visual inspections of trees increased from 4 to 17 USD/ha and costs of vectors' insecticide treatments increased from 240 to 1000 USD/ha per year.

In addition, many packing houses and processing plants closed, with significant declines in employment and it was estimated that losses reached more than 3.63 billion USD in Florida and that more than 6 600 jobs were lost.

The information above is based on the EPPO Datasheet on Huanglongbing disease, revised in 2020 by M.M. López, E. Marco-Noales and M. Cambra (IVIA, Moncada, Spain) and J. Cubero (INIA, Madrid, Spain). The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global Database (1), Global Database (2), Global Database (3)

Figures 13. Huanglongbing symptoms on sweet orange: leaf yellowing (left); dieback and leaf mottling (center); colour inversion of fruits (right). *Courtesy of S.A. Lopes (Fundecitrus, Brazil).*

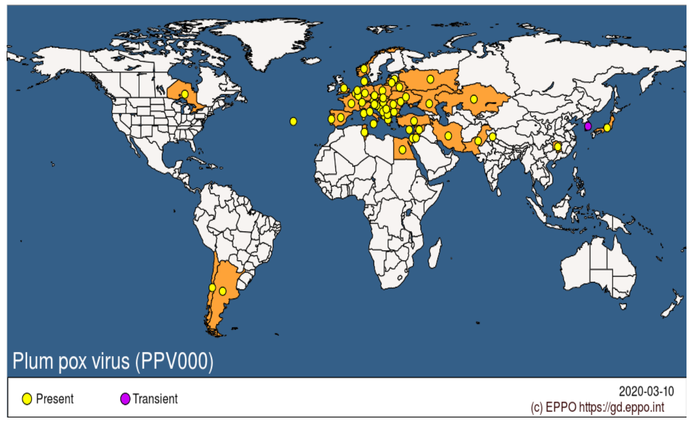
Plum pox virus

Plum pox virus, the causal agent of sharka, is one of the most studied plant viruses because of its high economic impact on stone fruit production.

Geographical distribution

Plum pox virus spread over most of the European continent and Mediterranean basin during the 20th century.

Plum pox virus had also been reported from the Americas, from Asia and from Africa. It is not yet officially reported from Oceania.



Hosts

The main woody hosts are the species of *Prunus* grown for fruit production, including apricot (*P. armeniaca*), peach (*P. persica*) and plum (*P. domestica* and *P. salicina*). Almond trees (*P. dulcis*) can be infected by *Plum pox virus* but show few symptoms. Natural infection of *P. cerasus* and *P. avium*, has been sporadically observed in Europe. *Plum pox virus* infects most wild or ornamental species of *Prunus*, such as *P. besseyi*, *P. cerasifera*, *P. insititia*, *P. spinosa*, *P. tomentosa*, serving as a potential reservoir and source of virus inoculum. Numerous annual cultivated plants or weeds have been shown to be experimental hosts of *Plum pox virus*, however their host status is unconfirmed and natural transmission between such herbaceous plants and Prunus has never been demonstrated in nature.

Economic impact

The disease incidence is particularly high in the fruit-producing areas of central and eastern Europe. Virus infection can lead to considerable yield losses, reaching 100%. European plums may show premature fruit drop, while Japanese plums and peaches show ring-spotting on fruit, and apricots show serious fruit deformation.

The information above is based on the EPPO Datasheet on *Plum pox virus*, revised in 2019 by T. Candresse (INRA, Bordeaux, France) and M. Glasa (SAS, Bratislava, Slovakia). The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global Database.

Plum pox virus

Figures 14. Sharka symptoms on fruits. *Courtesy of M. Yurtmen (Biological Control Institute, Adana, Turkey).*

Figure 15. PPV symptoms on apricot stone. *Courtesy of T. Jemrić (University of Zagreb, Zagreb, Croatia).*

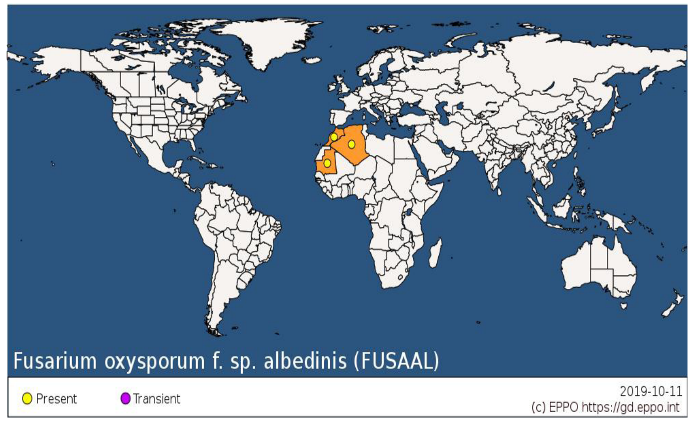
Figure 16. Ringspot symptoms of PPV on leaves. *Courtesy of M. Yurtmen (Biological Control Institute, Adana, Turkey).*

Fusarium oxysporum f. sp. albedinis

Fusarium oxysporum f. sp. *albedinis* is responsible for Bayoud disease of date palm *(Phoenix dactylifera)*.

Geographical distribution

The fungus is officially present in Algeria, Mauritania, Morocco.



Hosts

All commercial high-quality North African cultivars are susceptible (e.g. cvs 'Mejhoul', 'Deglet Nour', 'Bou Feggous'). Some cultivars show good resistance (cvs 'Black Bou Sthammi', 'White Bou Sthammi', 'Tadment', 'Iklane', 'Sair Layalet', 'Bou Feggous', 'Moussa' in Morocco and 'Takerboucht' in Algeria). However, among these cultivars, only cvs 'Sair Layalet' and 'Takerboucht' have dates of acceptable quality although not equal to cvs 'Deglet Nour' or 'Mejhoul'. Varietal selection has permitted the obtention of new varieties that combine resistance and good quality dates.

F. oxysporum f. sp. *albedinis* has also been reported on some other species of plants grown in date plantations: *Lawsonia inermis* (henna), a dye plant; *Medicago sativa* (lucerne) and *Trifolium* sp. These plants are symptomless carriers of the pathogen and are cultivated in North African and Near East countries.

The pathogen strains isolated from these plants are less aggressive compared to those isolated from infected palm leaves.

Economic impact

In the 20th century, the disease has destroyed more than two-thirds of the Moroccan palm groves (12 million trees), and it continues to cause the death of 4.5 to 12% of date palms per year. Morocco, which was formerly an exporter of dates, is now an importer. In Algeria, more than 3 million trees have been destroyed. Oases that formerly had 300-400 palms per hectare were reduced to 40-50 palms per hectare. The disease has caused not only the loss of a staple food for the Saharan population but also the loss of a major source of income and foreign currency.

Damage by bayoud disease has also reduced the annual crops formerly protected by date palms and has accelerated desertification.

The information above is based on the EPPO Datasheet on *Fusarium oxysporum* f. sp. *albedinis,* revised in 2020 by M. H. Sedra (Lab2a, Rabat, Morocco). The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global Database

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Fusarium oxysporum f. sp. albedinis

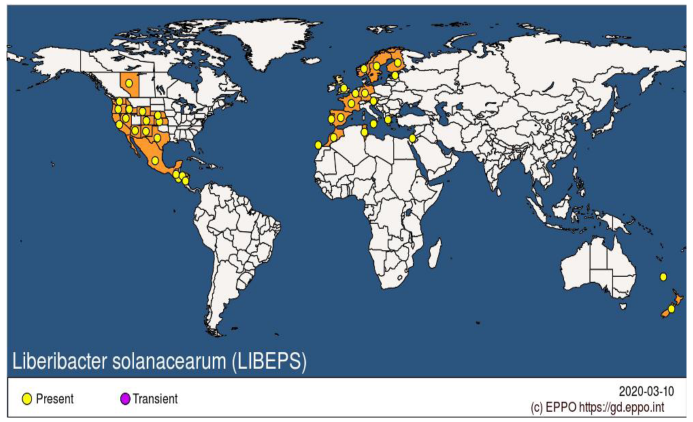
Figure 17. Bayoud disease of date palms in Morocco. *Courtesy of M.H. Sedra (Lab2a, Rabat, Morocco).*

Figure 18. Bayoud disease of date palms in Morocco. *Courtesy of M.H. Sedra (Lab2a, Rabat, Morocco).*

‘*Candidatus* Liberibacter solanacearum’

‘*Candidatus* Liberibacter solanacearum’ is a bacterium which was first identified in 2008 and shown to be associated with zebra chip disease of potato in North America. This disease was also observed almost simultaneously in New Zealand on potatoes and tomatoes. In the Mediterranean area and in Europe, ‘*Ca.* Liberibacter solanacearum’ has mainly been found in association with other plants, such as carrots and several other apiaceous crops.

Geographical distribution



Different haplotypes of ‘*Candidatus* Liberibacter solanacearum’ exist and differ in their host range, geographical distribution, and insect vectors (psyllids). Haplotypes D and E occur in Southern Europe and the Mediterranean region. The distribution of ‘*Ca.* Liberibacter solanacearum’ could be wider than that which has been reported.
The bacterium was detected in seeds coming from countries that had not reported it, e.g. Czech Republic, Denmark, Egypt, Japan, Lebanon, the Netherlands and Syria.

Hosts

‘*Ca.* Liberibacter solanacearum’ is known to primarily infect solanaceous species, including potato (*Solanum tuberosum*), tomato (*Solanum lycopersicum*), pepper (*Capsicum annuum*), eggplant (*Solanum melongena*).
The bacterium also infects apiaceous species including carrot (*Daucus carota*), celery (*Apium graveolens*), celeriac (*A. graveolens rapaceum*), parsnip (*Pastinaca sativa*), parsley (*Petroselinum crispum*), fennel (*Anthriscus cerefolium*).

Economic impact

The complex bacterium/vectors has caused serious damage to the potato, tomato and carrot industries. Based on the economic impact in Texas and New Zealand, the potential annual loss caused by zebra chip on solanaceous crops have been estimated to be 222 million EUR for Europe.

The information above is based on the EPPO Datasheet on ‘*Candidatus* Liberibacter solanacearum’, revised in 2020 by M. Loiseau (ANSES, Angers, France). The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global Database.

‘*Candidatus* Liberibacter solanacearum’

Figure 19. Potato plant with zebra chip and psyllid yellows symptoms infected by *‘Ca Liberibacter solanacearum’. Courtesy of J.E. Munyaneza (USDA, Konnowac Pass, USA).*

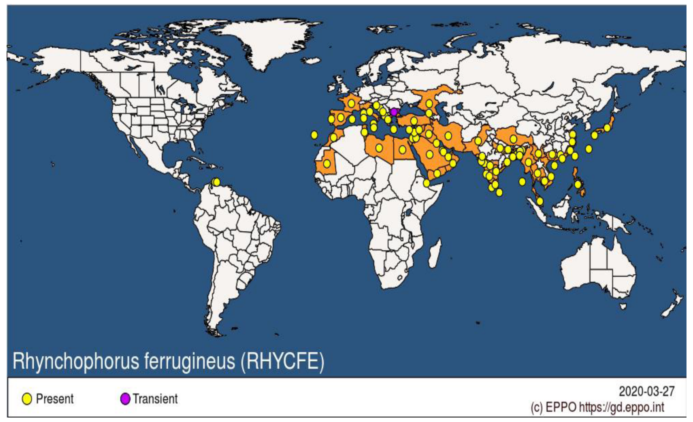
Figures 20. Zebra chip infected potato tuber (left); carrot plants infected by *‘Ca Liberibacter solanacearum’* (right). *Courtesy of J.E. Munyaneza (USDA, Konnowac Pass, USA).*

Rhynchophorus ferrugineus

Rhynchophorus ferrugineus, the red palm weevil, is a lethal insect pest of palms.

Geographical distribution

R. ferrugineus originates from South and Southeast Asia. However, since the 1980s its geographical range has been expanding, as the pest invaded other parts of the world, including the Mediterranean basin and the Near East. Ecological niche modelling has predicted that *R. ferrugineus* can expand its global range still further.



Hosts

The host range of *R. ferrugineus* has increased tenfold since the mid-1950s to cover 40 palm species, including *Cocos nucifera* (coconut), *Phoenix dactylifera* (date palm) and *Phoenix canariensis* (Canary palm).

Economic impact

In the Mediterranean basin, *R. ferrugineus* has become the major pest of palms, in particular on *Phoenix canariensis* which is very sensitive.

Direct losses due to *R. ferrugineus* are due to the loss of palms and the reduction in yield, as well as to the high cost of management programs.

In 2009, the loss incurred by the removal of severely infested palms in the Gulf region of the Middle East was estimated to be 5.18 - 25.92 million USD. In the period 2004-2009, in Spain, around 20 000 palms were killed by *R. ferrugineus*, and losses were estimated to be 16 million EUR. Furthermore, indirect costs are also substantial.

The most significant of these is due to the restricted movement of trees, especially their offshoots, resulting in drastic reduction in trade. In addition, chemical treatments and removal of the infested palms have negative impact on the environment and landscape, respectively, as well as on ecosystem services.

The information above is based on the EPPO Datasheet on *Rhynchophorus ferrugineus*, revised in 2020 by R. Faleiro. The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global database.

Figure 21. Wilting of the crown of ornamental palms (*P. canariensis*) infested by red palm weevil larvae. *Courtesy of R. Ferrara (NPPO Campania region, Italy).*

Figure 22. Collapsed ornamental palm tree infested by red palm weevil. *Courtesy of V. Martino (NPPO Campania region, Italy).*

Figure 23. Symptoms of red palm weevil on date palm (*P. dactylifera*). *Courtesy of A.M. D'Onghia (CIHEAM Bari, Italy).*

Figure 24. Adult of *R. ferrugineus*. *Courtesy of A. De Blasio (NPPO Campania region, Italy).*

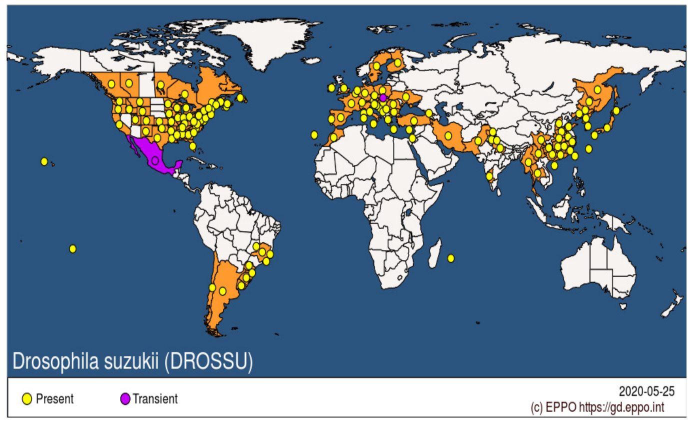
Drosophila suzukii

Drosophila suzukii, the spotted-wing drosophila, has become a major insect pest in Europe in just a decade.

Geographical distribution

Drosophila suzukii is endemic in Asia. It was first recorded as invasive in Hawaii in 1980 and then simultaneously in California and in Europe in 2008.

In the following years, it rapidly spread throughout most of the temperate regions of Asia, Europe, North and South America.



The use of predictive models has indicated that *D. suzukii* has the potential to further invade other areas in Africa and Australia.

Hosts

D. suzukii has been shown to possess a broad host plant range, but it shows a preference for red thin-skinned berries (e.g. cranberries, blueberries, strawberries, raspberries) and stone fruits (e.g. cherries, peaches, plums).

Economic impact

D. suzukii infestations generate direct and indirect economic impacts, through yield losses, shorter shelf life of infested fruits, extra labour and material costs for monitoring, field sanitation and post-harvest handling (especially in organic production) etc.

In Europe, a yield loss of 30-40% of blueberry, blackberry and raspberry fruits, was observed in Italy (in 2011) and up to 80% of yield loss occurred in strawberry production in France in 2010. This pest caused a loss of 3.3 million EUR, in 2011, in small fruits cultivation, in Trento province (Northern Italy).

These losses can be reduced or mitigated by the introduction of Integrated Pest Management (IPM) strategies.

The information above is based on the EPPO Datasheet on *Drosophila suzukii*, revised in 2020 by G. Anfora (FEM, Trento, Italy). The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global Database.

Drosophila suzukii

Figure 25. *Drosophila suzukii* on blueberry. *Courtesy of M. Maspero and A. Tantardini (Minoprio Foundation, Como, Italy).*

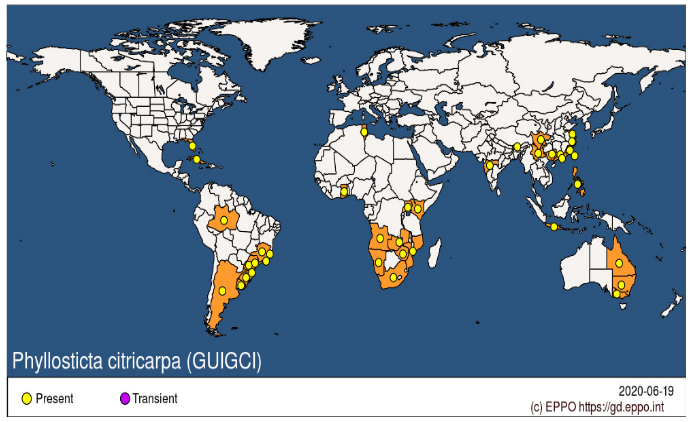
Figure 26. *D. suzukii*: oviposition scars on a cherry. *Courtesy of M. Hauser (CDFA, Sacramento, USA).*

Figure 27. Damage on strawberry tree fruits. *Courtesy of C.A. Coutinho (Conceição, Portugal).*

Phyllosticta citricarpa

Phyllosticta citricarpa, the causal agent of citrus black spot disease, was first described in Australia on orange (*Citrus sinensis*) at the end of the 19th century.

Geographical distribution



This fungal disease has been present for decades in many humid subtropical citrus-producing regions in Africa, Australia, Southeast.

Asia, and South America. In early 2010, *P. citricarpa* was discovered for the first time in the USA.

In 2019, the presence of *P. citricarpa* was officially confirmed in the Mediterranean Basin, in Tunisia, where official phytosanitary measures are being implemented to control the disease.

Hosts

P. citricarpa is a leaf spotting and fruit-blemishing fungus affecting *Citrus, Poncirus* and *Fortunella* and their hybrids. Except for *Citrus aurantium* (sour orange) and its hybrids, as well as *C. latifolia* (Tahiti lime), all commercially grown *Citrus* species are susceptible to *P. citricarpa.*

Economic impact

P. citricarpa is reported to cause yield losses and reduce the commercial value of fruits for the fresh market.
In Australia in 1931, all orchards of sweet orange cvs 'Washington Navel', 'Joppa' and 'White Siletta' were severely affected and losses of 80% were common in individual orchards. In South Africa in 1960's 90% of fruits from unprotected trees were claimed to be unfit for export and losses of more than 80% of unprotected fruits were reported to be common.

The information above is based on the EPPO Datasheet on *Phyllosticta citricarpa*, revised in 2020 by E. Kalogeropoulou (BPI, Kifisia, Greece). The full datasheet with more information on the pest can be viewed and downloaded from the EPPO Global Database.

Phyllosticta citricarpa

Figure 28. Symptoms of *P. citricarpa* on fruits of Valencia orange (EPPO Global database).

Figure 29. Symptoms of *P. citricarpa* on fruits of lemon. *Courtesy of Boughalleb-M'Hamdi (High Institute of Agronomy of Chott Meriem, Tunisia).*

2. Research priorities for the Mediterranean area

Baldissera Giovani, European and Mediterranean Plant Protection Organization (EPPO-Euphresco, France)

Research has a key role in underpinning plant health activities, ranging from pest risk analysis, 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.
Transnational research 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.

Countries around the Mediterranean basin may deal with the same harmful organisms: joining resources can accelerate the development of solutions without increasing the costs supported by each individual country; 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.

Countries in the Mediterranean area were surveyed to gather information on the plant health research priorities for the region, based on the Euphresco Strategic Research Agenda.

The research objectives that were highlighted as priorities by the experts that participated in the survey are presented in the next pages.

To improve knowledge on the biology, epidemiology and ecology of priority invasive and (re)emerging pests

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 pest risk analysis 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.

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 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.

To improve knowledge on emerging pathways of entry and means of spread for pests

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.

To expand knowledge on transmission of diseases and pathogens for healthy planting material

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/pathogen transmission and advice on the conditions that lower the risk during production and trade of planting material.
Collaboration with organisations involved in the production, certification and marketing of plants for planting (including seeds) will contribute to safer trade. Assessment and management of risks associated with other pathways will contribute to the development of a holistic view.

To test and validate methods for *in situ* detection and identification of 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 High-Throughput Sequencing.

Links between the activities in the field and in the laboratory should be strengthened.

To identify and validate strategies for control of pests resistant to pesticides and understand the genetics and epidemiological behaviour of resistant forms

Pest 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.

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, and on effects of different strategies.

3. Research infrastructures for the Mediterranean area

Maja Ravnikar, National Institute of Biology (NIB, Slovenia)
Mekki Chouibani, Near East Plant Protection Organization (NEPPO, Morocco)

It is not advisable to discuss research priorities without considering the infrastructures needed to implement scientific activities and nurture expertise. The term 'research infrastructures' refers to facilities, resources or services that are needed by the research community to conduct research in all scientific and technological fields. Research infrastructures provide the basis that allows the research community to work on phytosanitary issues.

If some of the research infrastructures presented in this compendium have existed in different forms for decades or even centuries (e.g. reference collections), they remain essential to support plant health activities. In other cases (e.g. molecular biology laboratories, databases), the infrastructures can contribute to more modern approaches and facilitate multi-disciplinary collaborations. The establishment of state-of-the-art infrastructures in all the countries of the Mediterranean basin would require huge means. When facilities exist, they may lack the necessary equipment, or simply chemical/biological reagents, which would enable them to be able to carry out their work in accordance with good laboratory practices and quality assurance standards.

The lack of co-ordination between the different structures at national and regional levels increases the problem of lack of funds and the inefficient use of available resources.

Available infrastructures should be interlinked when possible, in order to foster joint work and to facilitate the sharing of information and expertise. Important infrastructures identified by the respondents of the survey are presented below and in Figure 30.

Reference collections

Reliable collections are vital for identification of pest species and development of detection methods.

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.

Collections are often not available to scientists outside the organisation hosting them.

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. The research community does not need reference collections in every country or in every laboratory, but it 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 (for 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.

Digital infrastructures (computer facilities, databases, libraries, high capacity high-speed communication systems)

Publication of theories has been at the foundation of 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 searching of data in a few milliseconds and the amount of (scientific) data produced in the world is ever increasing. The use and re-use of data nurtures classic and novel research investigations and can help plant health activities.

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.

Containment facilities

When dealing with plant quarantine pests, it is not enough to have well-equipped research laboratories and adequate skills; it is mandatory to manipulate a pest or infected plant material in containment facilities with qualified personnel in order to ensure the conditions are in place to prevent the spread into the environment.

Therefore, research on regulated pests should be carried out in containment facilities that must fulfil technical specifications for quarantine purposes. These facilities must be well separated from those used to manipulate other organisms and meet several standards. As an example, for an insect-proof screenhouse, these standards would include: isolation from outside (e.g. double door entry, outward ventilation, double net or glass or other material, hard roof), isolation from the ground (e.g. concrete, gravel), water disinfection, soil sterilization, etc.

Equipment for supporting operations (e.g. storage areas, washroom, cold chambers, growing chambers, airflow purification systems) are also included to minimize contamination and movement into and out of the containment infrastructures.

Molecular biology laboratories

Molecular biology has become an essential part of diagnostic activities. PCR-related molecular methods in particular, are indispensable in all disciplines. For example they can allow the detection and identification of unculturable pathogens such as phytoplasmas and viruses, the identification of juvenile stages of insects, and distinction between different bacterial and fungal species.

Real-time PCR has become the reference method for the detection of pathogens that are present in low concentration in particular for asymptomatic plants.

Digital droplet PCR is another technique that could support plant diagnostic activities, in particular while preparing reference material in a context of quality assurance. More recently, High-Throughput Sequencing (HTS) has shown the potential to become a tool for plant health diagnosis, in particular as a generic first-line method for the diagnosis of unknown(s) or for mother plants testing in certification schemes; at the same time the technology will allow to generate more data on pest diversity which will support activities outside diagnostics.

To allow diagnostic laboratories to take advantage of these opportunities, equipment and training should be secured in order to develop/strengthen capacity on real-time PCR based techniques and HTS.

Curated databases and bioinformatic tools to process the large amount of data produced are also needed.

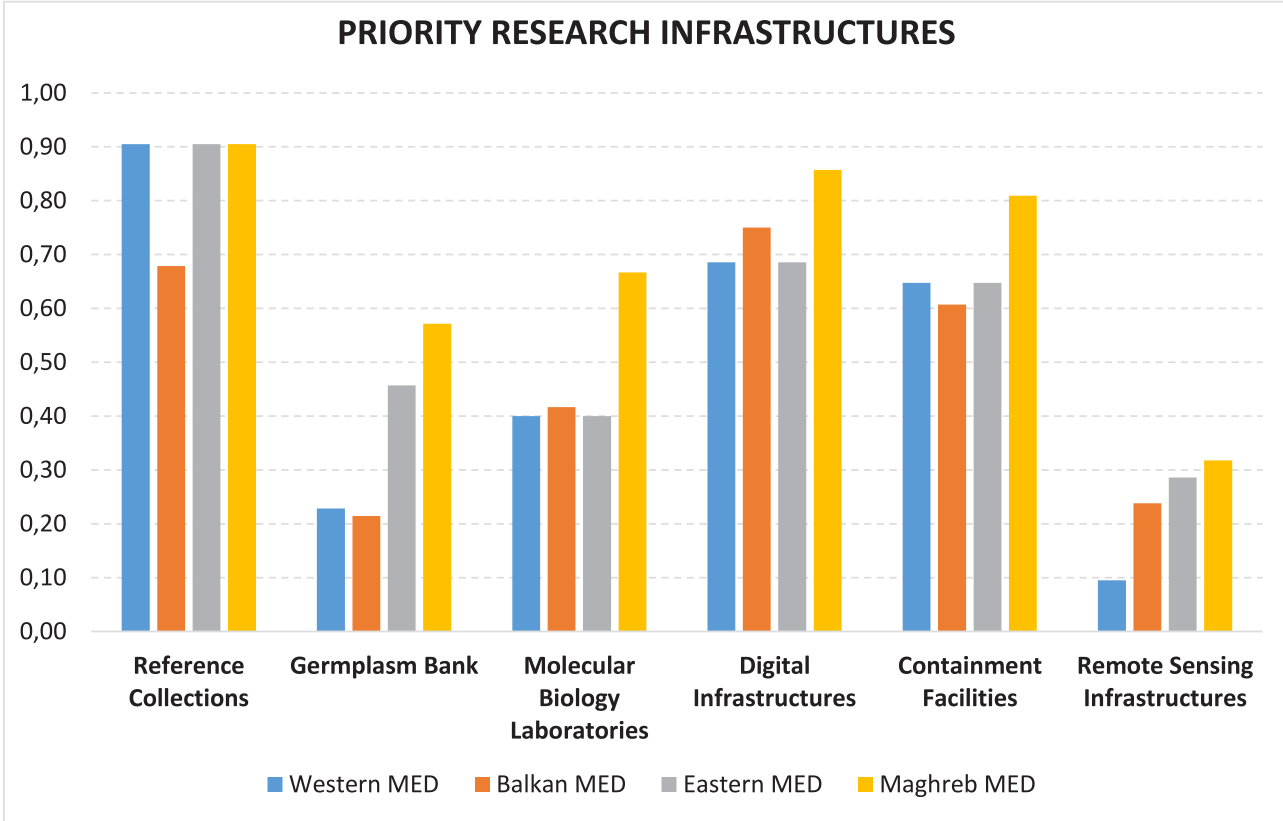


Figure 30. Quantitative graphic representation of the important research infrastructures for the 4 Mediterranean macro-areas cited in the survey. The data obtained from the countries surveyed vary from 0 (not a priority) to 1 (maximum priority). Infrastructures with score below 0.05 are not presented. *Data elaboration by F. Santoro, CIHEAM Bari, Italy.*

4. Research capacity for the Mediterranean area

Khaled Makkouk, Ibrahim Al-Jboory and Ahmed Katbeh, Arab Society for Plant Protection (ASPP, Lebanon)
Thaer Yaseen, Food and Agriculture Organization - Regional Office for the Near East and North Africa Region (FAO-RNE, Egypt)

The ability to prevent the introduction and spread of plant pests in a territory is mainly related to the quality of phytosanitary measures implemented and these measures should be science-based. A better phytosanitary status of produced and imported plants could be obtained by enhancing pest surveillance, diagnostics and control measures. Capacity building is then the key factor to develop and improve plant health (research) activities and knowledge gaps should be carefully considered.

In particular, capacity building should help enhance the quality of research activities for the development of environmentally-friendly pest control measures, border inspection, production of certified plant propagation materials, harmonized diagnostic protocols, innovative surveillance and early warning systems. It is however clear that governments alone cannot tackle the threats to plant health. Other stakeholders, including industry, non-government organisations, land-owners and the public, have an important role to play to protect the health of plants. Knowledge exchange should be promoted, e.g. through the creation of multi-partner research platforms to involve a range of stakeholders.

Important capacities identified by the respondents of the survey are presented below and in Figure 31.

Information Technology (IT)

Information technology allows accurate acquisition, storage, retrieval, transmission and manipulation of data. Knowledge is required on how to collect, harmonise, store and analyse data to enable rapid, precise and specifically targeted interventions when a phytosanitary issue is identified. Information technology provides numerous opportunities to support plant protection services. Data on partial or whole genome sequences can be used to identify micro-organisms and to track and trace particular strains; data on the exact host(s) distribution and the cultural practices and control measures can be used to instruct pest risk analyses; precise field data (e.g. geo-localization, sampling) provides the basis for statistical and epidemiological studies and can make monitoring programmes more effective.

Bioinformatics

The significant advances over the past few decades in molecular biology coupled with advances in genomic technologies led to a vast increase in the production of biological information. Bioinformatics has emerged as an interdisciplinary area that allows to manipulate biological information and generate new insights. Bioinformatics covers the development of computational tools and databases, and their use to better understand living systems.

Bioinformatics is instrumental in identifying new pest recombinants, supporting the development of new accurate pest diagnostic tools or developing crop varieties that are resistant to pests or that are more productive. Very few universities in the eastern and southern Mediterranean countries include bioinformatics in their (plant health) teaching programs, especially at the graduate level. In order to make progress in this area, and because of the complex nature of the discipline, institutions in the region should start developing educational programs that can integrate concepts from informatics, statistics, mathematics, chemistry, biochemistry, physics and linguistics. This is already in progress in other regions of the world, and it is not late to build capacity in the region.

Molecular biology

Advances in molecular biology (e.g. genomics, transcriptomics, functional genomics, DNA-based diagnostics, gene expression analyses and recombination) over the past few decades provided many potential solutions to several challenges including those related to plant health.

The institutional capacity of Mediterranean countries to employ molecular tools in solving plant health issues is variable between these countries and within institutions in the same country. In Albania, Algeria, Bosnia and Herzegovina, Croatia, Egypt, Kosovo, Lebanon, Libya, Macedonia, Morocco, Palestine, Tunisia, and Turkey there have been increases in the amount of research published in recent years. This suggests that improvements have been made in terms of research capacities but these are still considered below the desired level. To be able to increase the proportion of molecular biology research in these countries, more resources should be allocated to universities and research centres to improve existing facilities and increase training opportunities. Primary applications that require special attention are: (i) improving molecular diagnostics for pest identification, taxonomy and surveillance, (ii) improving phytosanitary status of planting material, (iii) employing molecular interference approaches to control pests, and (iv) using marker-assisted selection to breed for pest resistance.

Modelling

Mathematical/computer models provide a scientific and quantitative language to describe the complex relationships that lead to pest outbreaks. Modelling in plant health covers the following important areas: (i) risk assessment of plant pests and the development and evaluation of management schemes which help produce reduced risk options.

The key to the management of this risk is the identification of those pest species that are a priority for surveillance and which regions are at high risk of pest establishment under current patterns of trade/transportation and host suitability; (ii) models to estimate the impact of plant pests on crop yield and quality and on the environment; (iii) forecasting models to optimize pest monitoring and control. In addition, modelling is also useful to assess natural enemy distribution and their potential efficacy in biological control of crop pests.

The most commonly used modelling method is pest forecasting with the objective to achieve preparedness and adapt pest management strategies based on the expected risks. However, the use of such models is currently limited to some regions and not incorporated into wide integrated pest management programs.

Other useful forms of modelling related to pest risk assessment in the region are still in their infancy, and more efforts in this area are urgently needed in the coming years.

Strengthening collaboration between southern and northern Mediterranean countries in this domain may help in sharing models and expertise which will be instrumental in reducing the impact of pests.

Taxonomy

Taxonomy is the theory and practice of naming, describing and classifying organisms in a hierarchical level. The correct identification of a pest is a milestone and essential step in applying any phytosanitary measure.

Regulated organisms are known and treated based on their taxonomic name which is considered to represent a clearly delineated biological group with specific characters. As in other parts of the world, taxonomic expertise, which is needed to identify harmful quarantine organisms via their visual characteristics, is gradually decreasing.

Many experienced taxonomists have either passed away or have retired with no replacement by early-career scientists. Moreover, most of the newer taxonomists use molecular methods for pest identification, rather than traditional approaches based on external morphological or anatomical characters. Several studies performed with advanced technologies have revealed that in some cases both the historical taxonomic names and the associated pathological features are different from the accepted taxonomy.

It is of utmost importance that expertise is maintained, and taxonomy is revisited in interdisciplinary studies. Programmes to support taxonomic studies and research activities in Mediterranean countries should be encouraged. Collaboration should be initiated in order for field work to be conducted in a country and identification to be performed/ confirmed in another country in which more advanced identification tools, such as molecular techniques, are available.

Exchange of taxonomic research literature, which is very often extremely difficult to obtain, and exchange of pest specimens as reference material should be facilitated.

Finally, the development of pest identification keys for pests would be another area where collaboration could be sought.

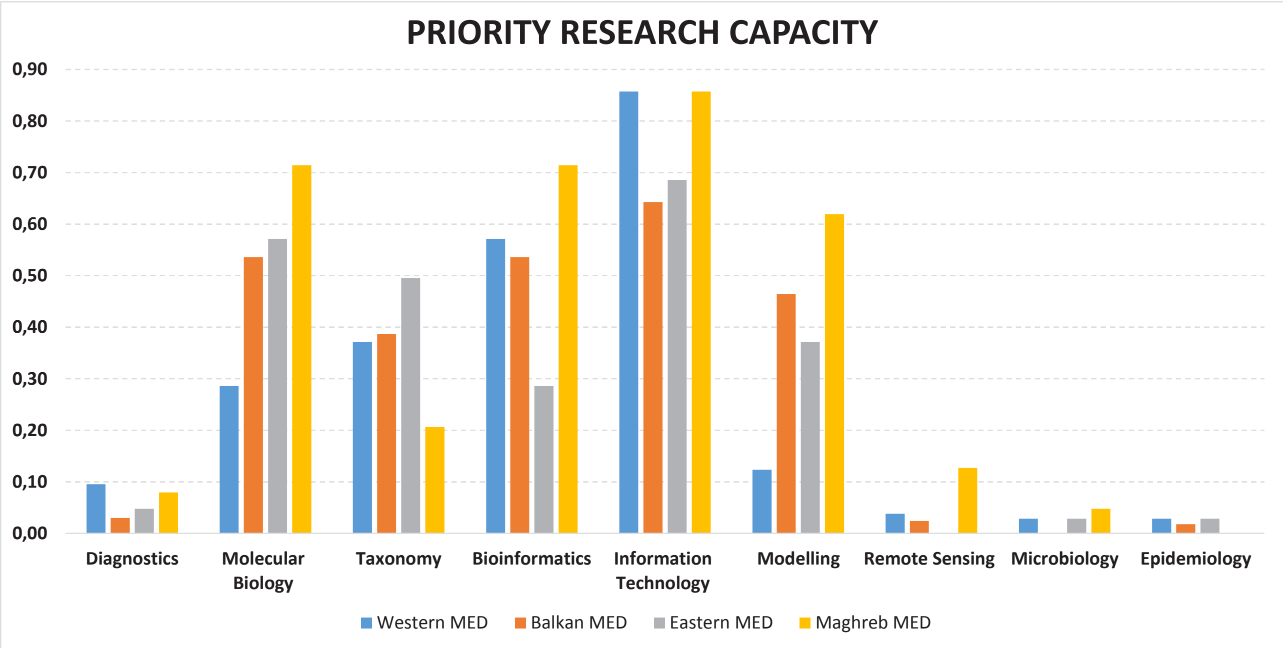


Figure 31. Quantitative graphic representation of the important research capacity for the 4 Mediterranean macro-areas cited in the survey. The data obtained from the countries surveyed vary from 0 (no priority) to 1 (maximum priority). Capacity with score below 0.05 is not presented. *Data elaboration by F. Santoro, CIHEAM Bari, Italy.*

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Euphresco

Compendium on the plant health research priorities for the Mediterranean region

A preliminary study coordinated by the International Centre for Advanced Mediterranean Agronomic Studies
and
the Euphresco network for phytosanitary research coordination and funding