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Identification of pests and pathogens recorded in Europe with relation to fruit imports

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Within the framework of the EU project DROPSA ('Strategies to develop effective, innovative and practical approaches to protect major European fruit crops from pests and pathogens'), a review on pests (including pathogens) that have fruit species as their host plants was conducted. The focus was on pests that have been introduced into Europe or were found in the fruit trade during the last 10–15 years. Among the 387 recorded pests, the following groups were identified: 1. fruit and vinegar flies, 2. scale insects, 3. fungi, 4. plant viruses, 5. bacteria, 6. pests of unknown risk, 7. tropical fruit pests, 8. pests that had an unexpected change of hosts, 9. fruit pests not likely to be transported on fruit and 10. 'hitchhikers' (non-fruit pests intercepted on fruit/fruit plants, fruit pests intercepted on other commodities than fruit). The large number of pests identified, from different taxonomic groups and origins, shows that fruit are an important pathway for pests, threatening fruit production in Europe.

Introduction

The EU project DROPSA ('Strategies to develop effective, innovative and practical approaches to protect major European fruit crops from pests and pathogens') started in 2014 and aims to improve plant health strategies in the fruit sector. The European and Mediterranean Plant Protection Organization (EPPO) and the Julius-Kuehn-Institute (JKI, Germany) carry out a task under work package 1: 'pathways of introduction of fruit pests and pathogens', as outlined in Steffen *et al.* (2015). The present article provides a full report of the first part of the task: a review of (potential) pathways of introduction of fruit pests into Europe.

The original aim of this review was to identify pests that have already been introduced into Europe with the fruit trade. However, in most cases it is difficult to ascertain on which pathways pests have been introduced. The pathway of introduction is often not known and, in most cases, the only information on pathways relates to potential pathways, based on the biology of the pest and its hosts. When looking at pests that have been introduced, as in many cases fruit are not concretely identified as a pathway, the only clear link to fruit crops is given when the pest has fruit species among its host range.

In addition, it was felt to be interesting to consider in this review the term 'introduced' in a broad sense. The definition of 'introduction' covers entry and establishment (ISPM 5, FAO, 2015). To get a broader view of what has happened in the past, an account of pests that have been intercepted in trade, or for which outbreaks were notified, was taken (whether or not they may then have been eradicated). This gives a more complete picture of past events, and an indication of pests that are spreading. For the next stage of the work this will also allow the identification of additional pests that may potentially be introduced.

As a consequence of both issues above, this review focuses on pests that:
-have been introduced, intercepted or caused outbreaks, and
-have host plants that are fruit species.

The review considers pests of fruit and nuts. 'Fruit' was not defined in the botanical sense, but as this term is used in the common language (see below). To provide a comprehensive overview of pests, data for the past 10–15 years were consulted (depending on the type of data). The bulk of the data was assembled until May 2014, and more recent information on introductions, outbreaks or interceptions is not mentioned.

Methods

Pests considered

The review takes account of pests that were introduced, intercepted or for which outbreaks were notified, as follows:

Introductions
Pests recorded in PQR database (EPPO, 2014) as being present in the EU or EPPO region[1] and introduced since 2000 were extracted. Host lists were screened to retain

[1]For the geographical range of the EPPO region, see the map at http://www.eppo.int/ABOUT_EPPO/images/clickable_map.htm

only pests of fruit species (see *'Fruit and nut species covered'*). The year 2000 date threshold was chosen in order to focus on relatively recent events, while providing a good history of introductions. The limitation of any date threshold is recognized: a pest first detected in 2002, for example, may have been introduced well before 2000.

Interceptions

A review was conducted of interceptions on consignments in 2003–2012 from EU Member States (approximately 15 000 interceptions, from Europhyt[2] and previous database versions) and from EPPO non-EU countries (approximately 850 interceptions, gathered by EPPO and published in the EPPO Reporting Service). In a first step, interceptions were retained, for which the consignment related to a fruit or vegetable species, and the type of commodity was 'fruit', 'vegetable', 'pot plant' or 'plant for planting'. In a second step, only those pests were kept that have fruit species as hosts (see *'Fruit and nut species covered'*) or were (incidentally) intercepted on fruit species.

As not all EPPO countries report interceptions of non-regulated pests, this information was specifically requested by the EPPO Secretariat. Some countries sent additional interception data regarding non-regulated pests, and those intercepted on fruit species were added to the list.

Interceptions reported at the genus level were kept only if no species of this genus was also intercepted (in which case only the species were listed).

Outbreaks

Outbreak notifications for 2004–2013 from EU member states (approximately 1500 notifications) were screened to retain only pests that have fruit species as hosts.

In both, interception and outbreak data, some pests are reported by individual countries, while they have established in some other EU countries before 2000 (and therefore do not appear in the data on introductions since 2000). These pests were kept on the list as it reflects pests of concern for the countries that intercept them.

Other sources

Many publications in the literature relate to alien species in Europe. The publication Roques *et al.* (2010) provides lists of alien arthropods in Europe, organized in chapters on individual taxonomic groups. Each chapter was screened to identify pests relevant for this review, i.e. those mentioned in relation to fruit species. Only species that had not been identified as introduced based on PQR were retained. This publication was chosen as it is recognized as a reliable and extensive source of information. Raspi *et al.* (2014) was also included as it provides information on the recent spread of a new drosophilid species. Due to time constraints, it was not possible to extend the review to a general study of the literature to identify other species that are not in the sources considered above.

[2]European Union Notification System for Plant Health Interceptions – EUROPHYT, see http://ec.europa.eu/food/plant/plant_health_biosecurity/europhyt/index_en.htm

Fruit and nut species covered

This review covers fruit and nut species as these terms are used in the common language, and not in the botanical sense, and thus excluded vegetables. For nut-producing species, the understanding is generally the same in both cases. There are few species concerned, and there were no difficulties in identifying nut-producing species in the pests' host lists.

This is not the case for fruit species, where there are many species and also different understandings. The interpretation of what is a fruit in the common language is in particular subject partly to cultural parameters, such as how the botanical fruit is used. There is a number of unambiguous cases, which are normally understood to be fruit species, such as those that are sweet and can be used raw [e.g. apple (*Malus domestica*), citrus (*Citrus* spp.), raspberries (*Rubus idaeus*), grapes (*Vitis vinifera*), tamarillo (*Cyphomandra betacea*), melon (*Citrullus lanatus*, *Cucumis melo*)] or in sweet preparations [e.g. quince (*Cydonia oblonga*)]. The species of fruit covered in the corresponding categories in Eurostat generally fall in this category.

At the other extreme, a number of species that produce 'fruit' in the botanical sense are not considered to be fruit in the common language. This is the case of species producing 'pods' [e.g. Fabaceae, cocoa (*Theobroma cacao*)] or 'grain' (e.g. cereals), as well as a number of species commonly considered as 'vegetables', such as sweet pepper (*Capsicum annuum*), pumpkin (*Cucurbita pepo*), cucumber (*Cucumis sativus*). Species producing berries may be considered as fruit, or not [e.g. raspberries are considered as fruit, coffee (*Coffea*) is not].

While most cases are clear, there is a grey zone of species that may be understood as, or classified as, fruit, vegetable or other, depending on the place, cultural factors, and how they are used. This is for example the case of avocado (*Persea americana*) (was kept) or olive (*Olea europaea*) (was not kept), as well as many minor tropical species, whose use is not clear and which may also be used for other purposes than food, such as medicinal purposes. In addition, in interception data, the commodity on which a pest was found may have been called 'fruit', where the species would normally not be considered as such [e.g. cassava (*Manihot esculentum*)].

The review did not attempt to solve all such issues, but for 'borderline' cases decisions were made, on whether the species should be listed among the fruit hosts for the pest concerned. The intended use of the fruit was considered, especially, whether it could be traded fresh or not (e.g. *Olea europaea*) and other parameters. For example, tamarind

(*Tamarindus indica*) was retained (although it is a pod-producing Fabaceae species), because it is named in Eurostat in a category containing 'minor' tropical fruit species.

The species covered vary for different genera and families: while most Rutaceae were retained (including all *Citrus* species), only watermelon (*Citrullus lanatus*), muskmelon (*Cucumis melo*) and balsam apple (*Momordica balsamina*) were retained for Cucurbitaceae. Finally, pests of hosts belonging to genera that comprise many fruit species, e.g. *Prunus*, *Juglans* and *Citrus*, were generally retained.

Solanaceae present a special case, among which goji (*Lycium chinense*), pepino (*Solanum muricatum*), tamarillo (*Cyphomandra betacea*, *Solanum betaceum*) and *Physalis* are generally considered as fruit, and are traded as such. Many pests of solanaceous species are polyphagous, although they are mostly recorded in relation to major crops, such as *Capsicum*, *Solanum melongena* (eggplant), *Solanum tuberosum* (potato) and *Solanum lycopersicon* (tomato). In recent EPPO PRAs (such as '*Candidatus* Liberibacter solanacearum' and *Neoleucinodes elegantalis*), there were often uncertainties attached to the host status of minor species of Solanaceae. Consequently, a few pests of Solanaceae that were only reported from tomato, eggplant, *Capsicum* or other solanaceous vegetables, although those were not considered as fruit as explained above, were retained in the list (even if no other host was recorded). This approach was followed in order to give an indication in relation to other solanaceous species that are not commonly recorded in host lists and not at all in trade data.

Information gathered

The information below was gathered for each organism. The items named below correspond to the structure of the list provided in an Excel spreadsheet that was produced for this review (see the section 'Outcome').

EPPO information resources were used as the primary source of information, especially the PQR database (EPPO, 2014) in relation to identity, distribution, host plants, categorization, and EPPO datasheets for possible pathways and information on damage. Where data were not available or insufficient in EPPO references, other sources of information were consulted, such as the CABI Crop Protection Compendium (CABI, 2014).

Identity

- *Scientific name of the pest*. This gives the species or genus as identified during the search.
- *Type of pest*, *Taxonomy*. The categories aim to be informative, and the taxonomic levels are not consistent across all groups of organisms. For most groups the order and family are indicated.
- *EPPO Code*. When available, the EPPO code is indicated.
- *Common names*. Where available, one or a few major common names in English are indicated. For viruses, the acronym is indicated.

Reason for adding to the list

The column 'why' records if the pest was added because it was introduced, intercepted, outbreaks were found, or other reason, as explained above (under *'Pests considered'*). Several categories are indicated when the pest was found in several of the sources.

Distribution in the EU, EPPO non-EU countries and other regions/countries

The list indicates the presence in the EU, in EPPO non-EU countries and in other regions and countries. PQR was used as the main source of information on distribution. Other sources were consulted when information was lacking in PQR.

- *Presence in the EU*. This covers the current 28 Member States. When the data originated from PQR, the field indicates the years of first record (if available) and pest statuses (in line with ISPM 8, FAO, 1998) in the categories of transience (under eradication) and absence (i.e. confirmed by survey, no longer present, eradicated, intercepted only, unreliable record, no record, invalid record). For other sources, the reference is indicated, sometimes with additional details.
- *Presence in EPPO non-EU countries*. This covers the current 22 EPPO non-EU countries, as well as territories of some EU Member States that are considered to be part of the EPPO region, but outside the EU plant health regime: Azores and Madeira (Portugal), and the Canary Islands (Spain). These were listed here only if the pests were not recorded on the mainland of these countries.
- *Presence in other regions/countries*. The regions considered were Africa, North America, South America, Central America, Caribbean, Asia and Oceania. Only regions are named if pests are present in more than five countries (all three countries in the case of North America). In other cases, individual countries are indicated.

Distribution data are more reliable for pests that are very well documented, for example in the EPPO system (and the distribution is detailed in PQR) or in the CPC (CABI, 2014). For others, the references used may give only a partial image of the distribution, or contain records that may need to be checked further. However, these data already indicate whether a pest may be present in the EU or not.

Host species

This considers all hosts and fruit and nut species, in two columns:

- *Hosts (all)*. This gives a complete host list (scientific names) as indicated in PQR or other sources when data are lacking in PQR. For pests with very many host species, the lists were shortened to include general considerations and specific examples. This is in particular the case for many scale insects. When data were extracted

from PQR, hosts are classified according to the categories in PQR (major, minor, incidental, wild – it should be noted that artificial hosts are not mentioned).
- *Hosts (fruit).* Fruit and nut species were extracted from the previous field, based on considerations detailed under *'Fruit and nut species covered'*. For pests that attack many species of a genus that contains many fruit or nut species, only genera are indicated (e.g. *Citrus*, *Juglans*, *Prunus*, *Vitis*).

Pathways
Information on known and possible pathways is listed in two fields:
- *Possible pathways (from biology).* Information in this field identifies possible pathways depending on the biology of the pest. This is based on publications where this information is indicated (most commonly EPPO datasheets or PRAs), known interceptions, or the assessors' own assessment. This field is not completed in all cases and contains only hypotheses, as a complete PRA would be needed to determine possible pathways.
- *Known pathways for international movement*. Known or suspected pathways for introduction into specific countries are listed, in the few cases where they are available. Interceptions also give an indication of pathways, and commodities and origins of interceptions are also listed here in a summarized form.

Type of damage
Information on damage is given based on the few sources consulted, and is indicated for some pests only. It is however considered useful to record the diversity of impacts.

Comments
This column records any additional data of particular interest for the pest concerned. In particular, notifications of outbreaks are indicated in this field.

References
PQR and other references used are listed. A list of references is available.

Categorization EPPO/EU
This records whether the pest is regulated in the EU, or listed on EPPO A1/A2 Lists of pests recommended for regulation as a quarantine pest. It also indicates if the pest is or was on the EPPO Alert List.

Outcome

The list of pests and information was gathered in an Excel file containing 386 species or genera, of which 264 are insects. The list will become available as a deliverable of Dropsa.

It should be noted that this list cannot be complete: firstly some pests intercepted on fruit in some countries may not have been notified, and outbreaks are not necessarily notified if the pest is not regulated. In addition, if the host lists in the literature are incomplete and do not include fruit hosts, the pest would not have been listed (with the exception of some pests of Solanaceae as explained above, under *'Fruit and nut species covered'*).

From the list of pests, a number of groups was determined that highlight important elements with regard to the introduction of pests of fruit species. Although the original task related solely to pests that have been introduced into Europe with the fruit trade, the review also identified many pests that were not introduced with fruit, or for which the pathway of entry is not known and can only be assumed from the information available on the biology of the pest. It was therefore considered too restrictive to focus only on the pests that have a clear association to the fruit trade. Analysing some groups of pests that do not necessarily relate to the fruit trade is useful in order to illustrate the diversity of pests of fruit species and of their introduction into Europe. Consequently, the selected groups cover both pests that are more likely to have been introduced with the fruit trade, and others that are less likely to have been introduced with the fruit trade. The results of this analysis were also used further in the DROPSA project, when studying pests of individual fruit species, in order to focus searches on groups of pests that are very likely to be introduced via the fruit trade.

The groups are analysed below and a summary for all organisms mentioned is presented in Appendix 1.

Fruit and vinegar flies

Fruit flies (Order: Diptera, family Tephritidae, approximately 4400 species; The Diptera site, 2004) and vinegar flies (family Drosophilidae, approximately 3950 species, Gottschalk *et al.*, 2008) are very likely to be transported with fruit in international trade, because eggs and larvae occur in fruit, and early stages of infestation are rarely detected. Damage is caused through oviposition punctures in the fruit, around which necrosis may occur, internal feeding and exit holes in fruit and decomposition or premature drop of the fruit (CABI, 2014). Healthy fruit crops are attacked and lose their economic value.

Non-European Tephritidae are regulated in the EU Plant Health Directive (Annex I/A1) (Council of the European Union, 2000). As a consequence, fruit consignments imported into the EU are requested to be free from any non-European Tephritidae. They are regulated as a generic group, but a number of species are highlighted as examples in the EU Directive. For example *Anastrepha fraterculus, A. ludens, A. obliqua, Bactrocera cucurbitae, B. dorsalis, B. tryoni, B. zonata, Ceratitis quinaria* and *Dacus ciliatus* are frequently intercepted on exotic fruits such as guava (*Psidium guajava*), mango (*Mangifera indica*), passion fruit (*Passiflora edulis*), custard apple (*Annona* spp.) or jujube (*Ziziphus* spp.), as well as on temperate fruit like apple (*Malus* spp.) or peach (*Prunus persica*). In addition, species that are not explicitly named in the EU Directive, such as *Bactrocera invadens,*

B. kandiensis, and *Ceratitis cosyra*, are frequently found during import inspections on mango or sugar apple (*Annona squamosa*), and *B. minax* on citrus species. Some of these fruit commodities are covered in the EU Plant Health Directive (Annex V/B1) and a plant health inspection is required. The fruit fly species mentioned above originate in all continents (except Antarctica) and have never established in Europe, maybe because of the difference of climate or the different ranges of host plants available in the area of origin compared to the EU. However, this does not rule out that establishment may be possible in the future.

Species of the genus *Rhagoletis*, that are also listed in the EU Plant Health Directive among Non-European Tephritidae, were not intercepted in the last 10 years. But outbreaks of *R. cingulata* (that attacks *Prunus* spp.)*, R. completa* and *R. suavis* (both feeding on *Juglans* spp.) occurred in EU member states, with unknown pathways. They are native to North America and have established in some EU countries (*R. cingulata* in Austria, Belgium, Croatia, Germany, Hungary, the Netherlands and Slovenia; *R. completa* in Austria, Croatia, France, Germany, Hungary, Italy and Slovenia; *R. suavis* in Germany). In this case, the climate, and possibly the host plants present in the area of origin and the EU are quite similar. It is worth noting that the related species *R. ribicola,* a pest of *Ribes* spp. originating from North America, is not mentioned in interceptions, outbreaks or introductions.

Drosophilidae are currently not regulated. Most species attack only overripe fruit that have already begun to rot. There are a few exceptions. *Drosophila suzukii*, a pest of all sorts of soft-shelled fruit, attracts attention as it is capable to lay eggs into healthy fruit, where larvae and pupae develop. It is native to Asia, has spread to North America in the 1980s and broke out in Europe for the first time in Spain in 2008 (Calabria *et al.*, 2012). Since then it has spread rapidly and is now present in 10 other European countries and Russia. In 2010, losses of up to 80 % were recorded in strawberry (*Fragaria* spp.) crops in France and also in raspberries (*Rubus* spp.) in Italy (EPPO, 2011a).

Zaprionus indianus is a drosophilid species that was intercepted in France on exotic fruits. It originates from Africa and has spread through Asia and over the American continent up to Canada. It has established in Italy and on the Canary Islands (Bächli, 2013). It is often associated with damaged or fallen rotting fruit, e.g. kiwi fruit (*Actinidia* spp.), dates (*Phoenix dactylifera*), grape (*Vitis* spp.), pomegranate (*Punica granatum*), jujube, banana (*Musa* spp.) (Al-Jboory & Katbeh-Bader, 2012), but is able to infest figs on the tree (*Ficus carica*) (Renkema *et al.*, 2013). There is conflicting information on the presence of *Z. indianus* in additional EU countries. The related species *Z. tuberculatus* has also been recorded in the EU, most recently in Italy.

Scale insects

There are about 7500 species of scale insects (order: Hemiptera, suborder: Sternorrhyncha, superfamily: Coccoidea) (ScaleNet, 2014). Some are serious plant pests, causing damage by removing plant sap or producing honeydew that may result in the growth of sooty mold covering leaf surfaces and reducing photosynthesis. In international trade they have been found and intercepted on all above-ground parts of traded plants, including fruit. However, this study did not identify an example where fruit were clearly identified as a pathway leading to the establishment of a scale insect in the EU.

Two *Aonidiella* spp., *A. citrina*, the California yellow scale, and *A. aurantii,* the California red scale were introduced into the EU. Both are originally Asian pests that have spread through tropical and other regions of the world. *A. aurantii* proved more competitive and displaced *A. citrina* in Southern California (DeBach *et al.*, 1978). Both species are polyphagous and have *Citrus* spp. as their main hosts (CABI, 2014). Defoliation, dieback of twigs and dropping of fruit occurs in heavily infested plants; attacked fruit lose their economic value (Bedford, 1998). While *A. citrina* has been regulated since 1992 [Plant Health Directive Annex II/A1, on plants of *Citrus*, *Fortunella* (cumquat) and *Poncirus* (hardy orange), but not on fruit], *A. aurantii* is not regulated. Nevertheless, *A. citrina* was later recorded as established in parts of France (2001), Greece and Italy (1994). *A. aurantii* was introduced to the EU as well and established in Cyprus, France (restricted distribution), Greece (Crete), Italy (Sardinia, Sicily), Malta and Spain.

Unaspis citri, the Citrus snow scale, is native to Asia and has spread to North, Central and South America, Africa and Oceania. It was introduced to the Azores (Portugal) and Malta, despite being regulated in the EU (Plant Health Directive Annex II/A1, on plants of *Citrus*, *Fortunella* and *Poncirus*, but not on fruit). It is a pest mainly of *Citrus* and was intercepted on *Citrus* and *Vitis* fruit. Infested plants show abnormal leaf fall, dieback of stems and branches and discoloration of fruit; weakened limbs and twigs often become infected with fungi (CABI, 2014).

Examples of other non-regulated scale insects with a restricted distribution in the EU are as follows:

- *Maconellicoccus hirsutus*, the Pink hibiscus mealybug, was introduced to Cyprus in 2010, where outbreaks on *Hibiscus*, *Vitis* and *Psidium* plants were reported. Other hosts are *Citrus*, *Mangifera indica* and *Annona*, on the latter it was intercepted on fruit. Throughout the world it has tropical and subtropical distribution.
- *Pseudococcus comstocki*, the Comstock mealybug, is a native Asian pest, but was intercepted on *Malus* fruit from the USA to Israel. In Italy an outbreak occurred on *Prunus persica* and it was also introduced to Croatia (1965), France (2004) and Portugal. Other hosts are *Musa*, *Pyrus* (pears) and *Vitis*.
- Less is known about *Pseudococcus maritimus*, the grape mealybug, whose presence is reported from North, Central and South America, Indonesia, Armenia and Poland (CABI, 2014; ScaleNet, 2014). It attacks *Malus*, *Prunus*,

Pyrus and *Vitis* and it has been found to be a vector of Grapevine leafroll-associated virus 3 and Little cherry virus 2 (Bahder *et al.*, 2013; Mekuria *et al.*, 2013).

- The mealybug *Delottococcus aberiae* is an African pest and has a relatively wide host range including guava, olive and apple. It was found at import inspections in the USA on citrus plants, and an outbreak occured on *Citrus* sp. in Spain and poses a potential phytosanitary risk to citrus and ornamentals (Miller & Giliomee, 2011; Beltrà *et al.*, 2013).

Some other scale insects are mentioned below (under *'Tropical fruit pests'*).

Fungi

Most phytopathogenic fungi belong to the classes Ascomycota and Basidiomycota and reproduce predominantly asexually (Rossman & Palm-Hernández, 2008). There are huge numbers of plant pathogenic fungi, for example 13 000 species of plant-associated fungi, occurring in the United States of America, are described in Farr *et al.* (1989). Fungal pathogens of fruit species are in many cases transported with infested plants for planting or on fruit.

Monilinia fructicola, the causal agent of brown rot of apple, which mainly attacks rosaceous stone fruits as well as *Malus* and *Pyrus* species, was regulated in the EU Plant Health Directive (Annex I/A1) until 2014, but was then deleted since it has spread considerably. During import inspections it was found on *Prunus* fruit originating from countries on all continents, where it is established. In the EU outbreaks were reported from Germany (2009), Spain (2006), Italy (2009), Romania (2010) and Slovenia (2009) on *Malus, Prunus, Pyrus* and *Rubus* species and it has also been introduced to France (2001), Hungary (2010) and Poland (2010). Successful eradication was reported from Austria and Slovakia. Yield losses are not easy to predict, because the state of the fruit as well as weather conditions influence the severity of damage (ripe and damaged fruit are most at risk, especially in warm and humid climates). Postharvest losses in the USA and also in Europe reached up to 90 % (it should be noted that the European data also included other *Monilinia* spp.) (EFSA, 2011).

Three species of *Phyllosticta*, that attack citrus and were found on fruit during import inspections, were identified during the review.

- *P. citricarpa* is frequently intercepted. It is present on all continents except Europe (and Antarctica). Phytosanitary requirements are made in the EU (Plant Health Directive Annex II/A1). In Brazil, *P. citricarpa* infections, leading to premature fruit drop, caused yield in oranges to decrease from approximately 161 kg/tree in fungicide-treated plots, to approximately 83 kg/tree in untreated plots (Araújo *et al.*, 2013). Several citrus species are attacked. Changes of trade patterns and practices (increased fruit imports to Southern EU countries, where citrus plants are grown; waste fruit or fruit peel may be discarded near orchards) have led to an increased risk of introducing the pest with fruit, because there is an increased risk of transfer (EFSA, 2014a).
- *P. citriasiana* is an Asian pest only known to infect pomelos (Wulandari *et al.*, 2009). It was found on pomelo fruit imports from China to the EU. This species was recently recognized as different from *P. citricarpa*.
- *P. capitalensis* is present in some countries on all continents. In the EU it has been introduced into Italy and Spain. In inspections it was found on grapefruit from South Africa. This species has a wide host range infecting for example fruit of citrus and guava or *Stanhopea* plants (Orchidaceae). In other plants, e.g. mango, it occurs as a leaf endophyte and does not cause symptoms (Glienke *et al.*, 2011).

Potebniamyces pyri, the causal agent of Phacidiopycnis rot, is restricted to North America. Pears, quinces and apples are hosts. It was found during import inspection on *Pyrus* fruit from the USA. Since Europe and North America have similar climates, there seems to be a risk of introduction into the EU (see also below under *'Pests of unknown risk')*.

Plant viruses

Plant viruses depend on biological vectors or mechanical transmission for plant to plant transfer. Inside the plant they spread from the place of infection to distal parts through the vascular tissue. Approximately 1300 species of plant viruses are recognized (Hull, 2013). A common means of international transport is with infected plants for planting. Introduction of viruses with the fruit trade can generally be considered as less likely than with plants for planting, due to the conditions to be met for entry and establishment. A notable exception is *Pepino mosaic virus* as explained below.

Tomato ringspot virus (ToRSV) is native to North America and natural spread depends on the presence of its vector nematodes of the genus *Xiphinema*. ToRSV is a quarantine pest for the EU (Plant Health Directive Annex I/A1). It has been introduced to Central and South America, Africa and Asia, New Zealand, a few EU countries (Croatia (1973), France, Italy, Lithuania, Slovakia, Slovenia) and EPPO non-EU member countries (Belarus, Jordan, Russia, Serbia, Turkey). From others it could be eradicated (e.g. Denmark, the United Kingdom, Norway). It can be transported in plants or plant parts, and attached soil may contain infected seeds or the nematode vector. A wide range of hosts is attacked, mainly *Prunus* spp., *Malus* spp., *Rubus* spp., *Vitis* spp. and *Pelargonium* spp., and it is less common on *Solanum lycopersicum*. Infection can cause foliar symptoms, reduced plant growth, a reduction in fruit set and even death of the plant. In a field study, infected raspberries showed yield losses of >50% in comparison to healthy

plants and infected fruit weighed 21% less than healthy fruit (Converse & Stace-Smith, 1971).

Citrus tristeza virus (CTV) is a pest mainly of orange and bitter orange, but other species of the family Rutaceae can also be attacked. Its origin is probably in Asia and it is now widespread, occurring in almost all citrus growing countries; in the EU it has become established in Croatia (1990), Cyprus, Greece, Italy, Portugal and Spain. It is spread via infected plant material and easily transmitted by grafting or by vector aphids. For the moment, the most efficient vector (*Toxoptera citricidus*) has a very limited distribution within the EU. CTV is a regulated quarantine pest (EU Plant Health Directive Annexes II/A1, II/A2, II/B). It is regulated on plants for planting from outside the EU, and on fruit (only those accompanied with leaves and peduncles) to certain protected zones within the EU. During import inspections it was intercepted on *Citrus* and *Fortunella* plants for planting. Several strains are known, causing different symptoms. In asymptomatic hosts, for example mandarins, latent infections occur, whereas susceptible hosts commonly become stunted and show chlorosis, stem pitting and reduced fruit growth.

The highly contagious *Pepino mosaic virus* (PepMV) does not depend on a vector for spreading. Because PepMV is mechanically transmitted, planting, pruning and fruit-picking are activities that can easily spread the virus through the crop at tomato fruit production sites. The virus may remain viable on clothes, tools, etc. Infected fruit are considered a likely pathway of introduction. It was described in Peru on pepino (*Solanum muricatum*) and was found in the EU for the first time in 1999, in the Netherlands, on tomato. This is the only case identified in this review, where infected fruit are a likely pathway of introduction for a virus.

Bacteria (including Liberibacter and phytoplasmas)

The diversity of plant pathogenic bacteria is much lower than that of fungi or viruses. Approximately 200 species are named (Bull *et al.*, 2010, 2012). Some of these have numerous pathovars or subspecies (e.g. *Clavibacter michiganensis*, *Pseudomonas syringae*, *Xanthomonas campestris*), which may have very different host ranges. Symptoms of bacterial diseases vary and include lesions on leaves and fruit, defoliation and premature fruit drop, cankers. In fruit crops, bacteria may lead to severe yield losses and sometimes death of plants. Many of the species (or pathovars) identified in the review, such as *Xanthomonas axonopodis* pv. *citri*, grapevine flavescence dorée phytoplasma or *Erwinia amylovora*, have catastrophic consequences on the crops attacked, even if they do not necessarily kill their host.

The mechanisms for local spread of bacteria vary depending on the species. Transmission with water is common, while only a few bacterial pathogens are seed-transmitted (e.g. *Acidovorax citrulli*) or vector-transmitted (e.g. *Liberibacter*, *Phytoplasma*). Internationally, the most likely pathway of introduction for bacteria is with plants for planting (including seeds in the case of seed-transmitted species) and most interceptions for bacteria identified in this review relate to these commodities. One exception is *X. axonopodis* pv. *citri*: despite the fact that it is currently regulated in the EU, with the requirement to attest that citrus fruit is free from the bacterium prior to import, it is often intercepted on *Citrus* and *Momordica* fruit during import inspections. Although *X. axonopodis* pv. *citri* can be associated with and survive on fruit (and also associated leaves), transfer to suitable hosts is a limiting factor for its introduction with fruit (USDA, 2008). EFSA (2014b) notes that current literature, in particular the few experiments conducted on transfer, suggests that transfer is unlikely; however, there are uncertainties on whether specific factors may play a role, such as the disposal of fruit waste close to orchards.

Among the 22 species, pathovars or subspecies identified in the review, 13 are regulated in the EU and 2 are subject to emergency measures (*Xylella fastidiosa* and *Pseudomonas syringae* pv. *actinidiae*). Most are already present in the EU, but have a limited distribution and are regulated to prevent their further spread (A2 pests, such as *Ralstonia solanacearum* and most phytoplasmas identified). Only *Xylella fastidiosa* and *Xanthomonas axonopodis* pv. *citri* are A1 pests. However, an outbreak of *X. fastidiosa* was found recently in Italy and is under eradication; it is worth noting that *X. fastidiosa* was found on *Olea europaea* (olive) and *Prunus dulcis* (almond), but not on many of the other fruit tree species attacked by other strains in California (EPPO, 2014a).

The eight introduced species that are not regulated in the EU are still present with a limited distribution and seem to have spread slowly. *Xanthomonas perforans* was detected in 2011 and is reported in only one EU country, while *X. arboricola* pv. *corylina* was already found in the 1970s, but is present only in 8 EU countries. Regulated species of *Xanthomonas* (*X. arboricola* pv. *pruni* and *X. fragariae*) seem to have a similar slow spread. Similarly, the seed-transmitted *Acidovorax citrulli* was recorded in Greece and Hungary in mid-2000s and has caused outbreaks in Italy and Spain only (EPPO, 2014b, under development). It was added to EPPO A1 List in 2014. All phytoplasmas in the review also have a limited distribution in the EU, as well as *Pantoea ananatis* and *Pseudomonas syringae* pv. *actinidiae*. Although *Erwinia chrysanthemi* has banana (*Musa* x *paradisiaca*) and pineapple (*Ananas comosus*) on its long host list, it has been intercepted on tissue cultures and plants for planting of ornamentals from Asia; it has been introduced to (and established in) 15 EU countries.

For vector-transmitted bacteria, infectious vectors on host commodities are generally considered as a potential pathway (EPPO/CABI, 1997). Vectors of *Xylella fastidiosa* are for example regulated in the EU (as non-European Cicadellidae, such as *Carneocephala fulgida, Draeculacephala minerva,*

Graphocephala atropunctata; Annex I/A1). The role of vectors in introducing '*Candidatus* Liberibacter solanacearum' has also been suspected in New Zealand (alongside that of plants and fruit) (EPPO, 2012). It is transmitted by the tomato/potato psyllid *Bactericera cockerelli* and possibly other psyllids. Vectors are more likely to be intercepted than the pathogens they transmit: for example both '*Candidatus* Liberibacter asiaticus' and *Diaphorina citri* are regulated in the EU, but only *D. citri* has been intercepted. Detection and identification at inspection of insects is usually easier than for bacteria. Some bacterial species may also be present in asymptomatic fruit, so detection is only possible if samples are taken for further testing.

The review also identified other Cicadellidae, which may or may not be vectors of phytoplasmas.

- *Orientus ishidae* is considered as a potential vector of grapevine flavescence dorée phytoplasma, it is spreading in the EU and its importance still not fully known (Koczor *et al.*, 2013).
- *Erasmoneura vulnerata* is not mentioned as a potential vector, but it is a minor pest of grapevine, originating from North America and now present in Italy and Slovenia (Seljak, 2011).

Vectors also play an important role in the natural spread of bacteria once introduced from other continents.

Pests of unknown risk

The review identified a number of pests that have not been identified as being of quarantine interest, and are therefore not regulated, but are pests of important crops. Some are already well established in the EU, some have caused outbreaks, others have only been intercepted. They have in common that their potential importance, and their pathway of introduction, are not always known. A few examples are detailed below.

Aphis illinoiensis (Aphididae) is a pest of grapevine, which originates from the American continents. First recorded in Turkey in 2002, it has since spread rapidly to a large part of the Mediterranean area. Its potential importance is not known, but so far it is a minor pest. There seem to be conflicting opinions in its countries of origin regarding its possible role as a virus vector (Havelka *et al.*, 2011; Mifsud & Pérez Hidalgo, 2011).

Several Coleopteran pests were notified in the EU, all of which may cause damage on strawberry or other crops. These pests are similar in that they are pests of plants only in some circumstances. They would normally not be identified as a pest risk, and it is also difficult to anticipate their importance in case of introduction. (This is similar to the case of *Zaprionus indianus* and *Z. tuberculatus*, which belong to the family Drosophilidae, which normally attack overripe fruit only; see also the section *'Fruit and vinegar flies'*). Examples are:

- *Ataenius picinus* (Scarabeidae) is present in the Americas (Central and South America, South-Eastern USA, Caribbean) and Oceania. It was first reported in Italy in 2010 (Inghilesi *et al.*, 2012). It is considered by Stebnicka (2004) as a minor pest, whose larvae attack seedlings and adults feed on strawberries, potatoes and beans. Adults are also coprophagous (EPPO, 2011b). No damage was recorded in Italy so far.
- *Stelidota geminata* and *Carpophilus lugubris* both belong to the family of sap beetles (Nitidulidae), which normally feed on a variety of material, including crops. *S. geminata* originates from the American continents. It was firstly detected in the Azores (Portugal) in the 1980s and has since spread to continental Europe. It currently occurs in nine EU countries as well as in Serbia, Switzerland, and Turkey (EPPO, 2010; Spasic *et al.*, 2011). *S. geminata* is a significant pest of *Fragaria* in the USA, both through direct damage to mature fruit and to contamination of the harvested fruit. *S. geminata* also attacks mature fruit of other species. In the EU, outbreaks were reported in Germany on *Malus* and *Pyrus.* In Corsica (France), it is considered as a minor pest of strawberry (Fredon Corse, 2014). However, in Italy (first record in 1995), it was recorded in Piemonte in 2009, where infestations on strawberry were then observed in 2011 and severe damage in 2014 (Federazione provinziale Coldiretti Cuneo, 2012; Pansa *et al.*, 2014). It is unclear how the situation will evolve in Europe.
- Another sap beetle, *Carpophilus lugubris* is a pest of beehives. Incidentally, it also feeds on *Zea mays* (maize), and mature fruit (including strawberry). It was recorded in beehives for the first time in Italy in 2011, and its potential damage to crops is still unknown (Bernardinelli & Governatori, 2013; Marini *et al.*, 2013).

In addition to an unknown pest risk, there is always an uncertainty concerning the hosts that will be attacked. A number of Aleyrodidae in the review have broad host ranges. It is possible for a pest to enter on one pathway and transfer to another crop. For example *Aleuroclava aucubae* is a species of Asian origin, first detected in Italy in 2007, and found since in Slovenia and France. No particular economic damage is reported in the literature, but it is regulated by Australia and New Zealand. Outbreaks were reported on *Citrus* in France, while its host range is much broader and also includes *Morus alba* (mulberry) and *Prunus* (EPPO, 2013a,b).

While no interceptions are reported for *A. aucubae*, the related species *Aleuroclava psidii* has been intercepted on *Psidium guajava* fruit. This species has a wide host range, which includes *Citrus*. Similar data are available for *Paraleyrodes minei* that was intercepted on plants for planting of *Piper sarmentosum* (wild pepper), but an outbreak occurred on *Citrus*. Furthermore, *Trialeurodes abutiloneus* was intercepted on *Hibiscus*, but its host range includes many fruit species, such as *Citrus*, *Punica granatum*, *Pyrus communis* and *Rubus*.

Finally, large numbers of scale insects are intercepted, but are not regulated and the risk may not have been assessed. Some of them have already established in a few

EU countries, such as *Aonidiella aurantii*, and the risk may be identified only if and when they spread further (see also under *Scale insects*).

Tropical fruit pests

In some cases, fruit pests originating from the tropical regions of the world have been introduced to Southern European islands (such as the Azores, Canaries or Madeira, that geographically lie on the African plate), and later on they have been found on the European continent.

Diaphania indica, the cucumber moth, has its main distribution in the tropics and sub-tropics of Africa, Asia, the Carribean and the Pacific. It mainly attacks cucurbits, including the fruit species melon (*Cucumis melo*) and watermelon (*Citrullus lanatus*), by larvae feeding on leaves and fruit (CSL, 2005). In import inspections it was often found on gourds from Asia or Africa and it has established in Madeira (Borges *et al.*, 2008). It is a quarantine pest for the USA. Under laboratory conditions, reproduction was most effective at 35°C, but the different populations and strains that exist in the wild are probably adapted to different climatic conditions (Hosseinzade *et al.*, 2014).

Aulacaspis tubercularis, the white mango scale, is distributed in Africa, Asia, Oceania, South and Central America and the Caribbean and has established in Madeira (Borges *et al.*, 2008) and probably in Italy (Pellizzari & Dalla Montà, 1997). Mango is its main host, but it also feeds for example on avocado (*Persea americana*), coconut (*Cocos nucifera*), cinnamon (*Cinnamomum* spp.) and citrus, attacking the leaves, stems and fruit. Thus the export value of fruit decreases (see also under *Scale insects*).

The palm aphid *Cerataphis brasiliensis* is distributed throughout the tropical and subtropical regions of the world. It established in Madeira (Borges *et al.*, 2008) and the Canary Islands (Perez Hildago *et al.*, 2000) and an outbreak occurred in France (2004) on Pindo palms (*Butia capitata*) imported from Brazil (Germain & Chapin, 2004). Coconut, date and other palms are also hosts, and this pest may occur on fronds and occasionally on young fruit. Transport in international trade is most likely on plants for planting and rather unlikely on fruit. Honeydew production by the aphids promotes growth of sooty mold that can limit photosynthesis, young coconut palms can be seriously damaged and heavily infested palms can have stunted growth (Wells, 2012).

The pineapple mealybug *Dysmicoccus brevipes* is distributed over the tropical and subtropical regions of the world. Though particularly common on pineapples, it is highly polyphagous, attacking mainly fruit crops and ornamentals. It has established on the Azores, Madeira and in Italy (CABI, 2014). In import inspections it was found on pineapples from tropical countries. The grey pineapple mealybug *Dysmicoccus neobrevipes* is also polyphagous, it was found on mangoes from the Caribbean. Infestation results generally in reduced vigour of the host plant, discoloration of leaves and fruit and deposited honeydew may serve as medium for growth of sooty moulds. Crops are at risk especially in areas where the mealybug wilt of pineapple is absent, because introduced mealybugs might carry pineapple wilt-associated viruses.

The whitefly *Aleurotrachelus atratus* is native to Brazil and attacks mainly *Cocos nucifera* and other palms of the family Arecaceae, on which it may cause the growth of sooty moulds due to honeydew production, wilting and drop of leaves. It also attacks citrus and aubergine, but there is no data on the kind of damage for these crops. Plants for planting are the most important pathway for international transport. It was found in an import inspection of palm leaves from Mexico (Baufeld & Schrader, 2014). It is distributed in tropical and subtropical regions of South, Central and North America, Africa, Oceania and the Canary Islands. In the EU it was found in greenhouses in France and Great Britain.

Pests with unexpected changes of hosts

Some unusual cases were observed, where fruit pests were recorded on plant species that were not known to be a host. For example the mango thrips *Scirtothrips mangiferae* is a known pest of *Mangifera indica* in the Near East and Africa. In Spain, an outbreak was recorded on *Vaccinium macrocarpon* (cranberry) plants; this species has not been recorded as a host before. Mango thrips mainly breed and feed on young leaves, although occasionally breeding occurs on young fruit (Mound & Stiller, 2011).

The tomato bug *Cyrtopeltis tenuis* is distributed in Africa, Asia, Oceania, USA, Cuba, Puerto Rico, Saint Kitts and Nevis, Virgin Islands, Venezuela and also occurs in Cyprus, France, Italy, Turkey and Finland (CABI, 2014; EPPO, 2014c). It is mainly a pest of cucurbits and Solanaceae. In import inspections it was found on fruit of *Annona squamosa*, which was not known as a potential host. The bug feeds on stems, leaves, flowers and fruit and infestation may cause premature fruit drop and stunted growth of the host plant.

The mealybug *Paracoccus tripurae* is so far only reported from India, where it occurs on *Citrus* sp. (Williams, 2004). During import inspections in the EU it was found on fruit of *Annona muricata* (soursop) from Sri Lanka. Information on this pest is scarce.

Cucumber mosaic virus (CMV) has a wide host range. It is mainly a pest of Cucurbitaceae, Araceae and Solanaceae, but in Italy it broke out on *Actinidia* sp. (Actinidiaceae). It is seedborne and has spread worldwide, occurring on all continents. Systemic infections with the virus may be symptomless, but depending on strains and hosts, chlorosis and distortion of leaves and fruit may occur, as well as dwarfing of the whole plant.

Fruit pests not likely to be transported on fruit

Some pests that attack fruit plants are not likely to be transported on traded fruit. They live in the soil or in other parts

of the plant than fruit. This is for example the case with the following groups:

• Nematodes.

Aphelenchoides fragariae, the bud and leaf nematode, is a pest of strawberries and some other plant species from the temperate and tropical zones. It occurs in North America, Asia, Oceania and is widespread in Europe. Attacked plants produce malformed leaves, show stunted growth and do not produce fruit under heavy infestation (APPS, 2011). Import inspectors recorded it on plants for planting of several species including strawberry. A closely related species, the rice white tip nematode *Aphelenchoides besseyi*, infests mainly rice (*Oryza sativa*) and strawberry. It occurs worldwide, but was found only in few EU countries: Bulgaria (after 1970), Hungary (1970) and Italy (1973). It is a quarantine pest for the EU (Plant Health Directive Annex II) and strawberry plants for planting as well as rice seeds must be tested and found to be free from the nematode prior to import.

• Longhorn beetles (Cerambycidae).

Larvae of longhorn beetles bore into wood of trunk and branches, which can cause serious damage and mortality of their host tree. Adults generally feed on leaves or young shoots. No life stage is associated with fruit. Due to their biology, possible pathways in international trade are plants for planting, wood with bark or wood packaging material.

The citrus longhorn beetle *Anoplophora chinensis* and the Asian longhorn beetle *Anoplophora glabripennis* are Asian pests of mostly deciduous tree species. Both species are EU quarantine pests (Plant Health Directive Annex I/A1). Their host range includes *Citrus, Malus, Pyrus*. Outbreaks are under eradication in several European countries.

The redneck longhorned beetle *Aromia bungii* is native to Asia. It is a pest of *Prunus* trees. It was added to the EPPO A1 List in 2014. In 2011, an outbreak was found in Germany on *Prunus* trees and in 2012 in Italy. Both are under eradication.

The apple tree borer *Saperda candida* is a North American pest and has been introduced into Germany (2008). In 2010 it was added to the EPPO A1 List. It attacks *Malus* spp. and other (fruit) trees.

• Ambrosia and bark beetles (Scolytidae).

Ambrosia and bark beetle larvae mine the inner bark of trees and shrubs, often cause sap flow, and weaken their host; adults may be present in the bark or on the outer wood.

Phloeotribus liminaris, the peach bark beetle, originates in North America. It infests *Prunus* spp. and has been introduced to Italy (2003).

The walnut twig beetle *Pityophthorus juglandis* also originates from North America. It attacks *Juglans* spp. (walnut) and, together with the fungus *Geosmithia morbida*, causes thousand cankers disease, with leaf wilting, dieback of twigs and branches, cankers and tree death. Both pests were first found in Italy in 2013, and were added to the EPPO Alert list in 2014. Suspected pathways of introduction are walnut wood with bark and walnut plants for planting.

The ambrosia beetle *Xyleborus perforans*, called island pinhole borer, is native to Asia and Oceania. It has been introduced to Africa, North America (Canada, Hawaii), the Canary Islands, the Azores and Madeira (CABI, 2014; PQR). On the European continent it was only intercepted (Germany, Italy, Poland). It is polyphagous and its host range includes numerous fruit trees. Infested plants show wilting, dieback and a general decline in vigour. In international transport, host plants for planting, wood and wood products are likely to carry the beetle.

'Hitchhikers' (non-fruit pests that were intercepted on fruit/fruit plants, fruit pests intercepted on other commodities than fruit)

Species that do not depend or feed on fruit can sometimes be found 'hitchhiking' on fruit species commodities in international trade. Some examples follow:

- *Blissus diplopterus*, the grain chinch bug, whose distribution is restricted to South Africa, is a serious pest of cereals. Adults congregate in fruit trees to aestivate (become quiescent to survive a hot dry summer) (Malumphy *et al.*, 2012). It was intercepted on numerous occasions in import inspections on apple, citrus, nectarine, peach, pear and plum fruit from South Africa.
- The brown rover ant *Brachymyrmex obscurior* is a small ant which is native to Central and South America. It has been introduced to North America, some Pacific islands and the Netherlands. It feeds on honeydew produced by aphids or mealybugs, but during inspections it was found on pineapple fruit from the Dominican Republic.
- The parasitic wasp *Syrphophilus bizonarius* was intercepted on apple fruit from Italy to Israel. It is not a plant pest, but used as a natural enemy that parasitizes the larvae of the sorghum shoot fly *Atherigona soccata* (Bleton & Fieuzet, 1943). It is present in North America, Africa, Asia and Europe.
- The legume pod borer *Maruca vitrata* has in its host list different plants, especially from the family Fabaceae, but no fruit host. However, in import inspections it was found on vegetables belonging to the Solanaceae and Fabaceae from Asia and Africa, as well as on citrus fruit from Asia. Its presence has been recorded in Africa, America, Asia and Oceania; it is absent from Europe.
- The American cockroach *Periplaneta americana* is native to Africa, but has a cosmopolitan distribution. It is omnivorous and feeds on almost anything including decaying organic matter, clothes, paper, stored food. Due to its association with human waste it can become a public health problem. During plant health inspections it was for example detected on mango packaging from Asia and Yucca plants from the USA.
- Gastropod species, such as the vineyard snail *Cernuella virgata* and the brown garden snail *Cryptomphalus*

aspersus, were found on apples transported from France to Israel. *C. virgata* is a quarantine pest in Israel. Its distribution comprises Australia, Western Europe and Mediterranean countries and it feeds on decaying organic matter, pasture vegetation, crop seedlings and young shoots of vines, shrubs and trees (Noma *et al.*, 2010). *C. aspersus* is polyphagous and is widespread in Europe and throughout the world in regions with temperate, Mediterranean and even subtropical climates (CABI, 2014).

Finally, other species, such as *Halyomorpha halys*, the brown marmorated stink bug, feed on fruit, but 'hitchhike' on other commodities than fruit in international trade. *H. halys* is present in Asia, North America and the Caribbean, and has been introduced into Europe [Liechtenstein (2004), Switzerland (2006), France (2012), Germany (2011), Hungary (2013), Italy (2012)]. It is polyphagous, feeding on leaves, stems and fruit of various species including citrus, apples, pears and grapes. During import inspections, it was found on wood packing material (pallets).

Conclusions

A large number of pests of fruit species has been introduced into the EU (as well as EPPO non-EU countries) and in many cases, the pathway of introduction is not known. In addition to the possibility of moving on a pathway, there are other factors relevant for the successful introduction of a pest. Whether pests transported on fruit are able to establish at destination or not, depends on many parameters, including their biology, crop management practices and the possibilities to transfer to a host at destination. The large number of pests intercepted on fruit, from different taxonomic groups and origins, however, shows that pests do move in trade on fruit. Import inspections focus on regulated pests and consignments. Consequently certain types of pests are especially looked for and certain species of fruit are thoroughly examined, whereas fruit that are not hosts for any regulated pests are generally not inspected. Therefore, it can be expected that even more pests are associated with the fruit trade than those that are found during import inspections.

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Identification des ravageurs et pathogènes signalés en Europe en rapport avec les importations de fruits

Dans le cadre du projet DROPSA de l'UE («Stratégies de développement d'approches efficaces, novatrices et concrètes pour protéger les principales cultures fruitières européennes contre les ravageurs et pathogènes»), une étude a été menée sur les ravageurs et pathogènes qui ont des espèces fruitières parmi leurs plantes-hôtes. L'accent a été mis sur les organismes nuisibles qui ont été introduits en Europe ou trouvés dans le commerce des fruits au cours des 10-15 dernières années. Parmi les 387 organismes nuisibles listés, les groupes suivants ont été identifiés: 1. mouches des fruits et drosophiles, 2. cochenilles, 3. champignons, 4. virus, 5. bactéries, 6. organismes nuisibles de risque inconnu, 7. organismes nuisibles tropicaux, 8. organismes nuisibles passés sur d'autres hôtes, 9. organismes nuisibles d'espèces fruitières non susceptibles d'être transportés sur les fruits et 10. contaminants (organismes qui ne sont pas des nuisibles d'espèces fruitières mais ont été interceptés sur des fruits ou des plantes fruitières, organismes nuisibles d'espèces fruitières interceptées sur d'autres marchandises que les fruits). Le grand nombre d'organismes nuisibles identifiés, appartenant à différents groupes taxonomiques et provenant d'origines diverses, montre que les fruits sont une filière importante pour les organismes nuisibles (y compris les pathogènes), menaçant la production de fruits en Europe.

Обзор вредных организмов (включая патогены), зарегистрированных в Европе в связи с импортом фруктов

В рамках концепции DROPSA проекта ЕС («Стратегии по разработке эффективных, инновационных и практических подходов, позволяющих защищать основные европейские плодовые культуры от вредных организмов, включая патогены») был проведён обзор вредных организмов (включая патогены), растениями-хозяевами которых являются плодовые. Внимание было сосредоточено на тех вредных организмах, которые были интродуцированы в Европу или были обнаружены за последние 10-15 лет в ходе торговли фруктами. Среди 387 зарегистрированных вредных организмов были определены следующие группы: 1. плодовые мухи и дрозофилы, 2. щитовки, 3. грибы, 4. вирусы растений, 5. бактерии, 6. вредные организмы с неизвестным риском, 7. тропические вредные организмы на плодовых, 8. вредные организмы, неожиданно изменившие своих хозяев, 9 вредные организмы плодовых, которые не могли переноситься на фруктах и 10. засоряющие организмы (вредные организмы, не повреждающие плодовые, но выявленные на плодах или плодовых растениях, вредные организмы плодовых, выявленные на товарах, не являющихся фруктами). Большое число выявленных вредных организмов, принадлежащих к различным таксономическим группам и имеющих различное происхождение, показывает, что фрукты представляют собой важный путь распространения вредных организмов (в том числе патогенов), угрожающих производству фруктов в Европе.

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Appendix 1

Table 1 Species used as case examples in this review, with information on whether they were intercepted in import inspections or introduced into the EPPO region during the last 10–15 years, on their potential to cause damage to fruit crops, their regulation status in the EU and whether they are likely to be moved with fruit

Pest group	Species name	Intercepted	Present in EU	Damage[1]	Regulated in EU	Fruit as known or potential pathway[2]
Fruit flies[3] #	*Anastrepha fraterculus, A. ludens, A. obliqua, Bactrocera cucurbitae, B. dorsalis, B. tryoni, B. zonata, B. invadens, B. kandiensis, B. minax, Ceratitis cosyra, C. quinaria, Dacus ciliatus*	Yes	No	High potential to cause damage: Oviposition punctures in the fruit, around which necrosis may occur, internal feeding and exit holes in fruit, decomposition or premature drop of the fruit; healthy fruit crops are attacked and lose their economic value.	Yes (as Non-European Tephritidae)	Yes
	Rhagoletis cingulata, R. suavis, R. completa	No	Yes			
Vinegar flies[3] #	*Drosophila suzukii*	No	Yes	High (crop losses of up to 80% were recorded)	No	Yes
	Zaprionus indianus	Yes	Yes	Often associated with damaged or fallen rotting fruit, but able to invade figs.	No	Yes
	Zaprionus tuberculatus	No	Yes	–	No	Yes*
Scale insects[3] #	*Aonidiella citrina*	Yes	Yes	–	Yes (on plants of *Citrus*, *Fortunella* and *Poncirus*)	Yes
	Aonidiella aurantii	Yes	Yes	–	No	Yes
	Unaspis citri	Yes	Yes	–	Yes (on plants of *Citrus*, *Fortunella* and *Poncirus*)	Yes
	Maconellicoccus hirsutus	Yes	Yes	Severe infestations may cause defoliation and death	No	Yes
	Pseudococcus comstocki	Yes	Yes	–	No	Yes
	Pseudococcus maritimus	(Yes) (not in the EU, but in IL)	Yes	–	No	Yes
	Delottococcus aberiae	No	Yes? (outbreak in Spain)	–	No	Yes*
Fungi	*Monilinia fructicola*	Yes	Yes	–	No	Yes
	Phyllosticta citricarpa	Yes	No	Yield loss due to premature fruit drop	Yes (on plants of *Citrus*, *Fortunella* and *Poncirus*)	
	Phyllosticta citriasiana	Yes	No	–	No	
	Phyllosticta capitalensis	Yes	Yes	–	No	
	Potebniamyces pyri	Yes	No	–	No	

(continued)

Table 1 *(continued)*

Pest group	Species name	Intercepted	Present in EU	Damage[1]	Regulated in EU	Fruit as known or potential pathway[2]
Plant viruses	*Tomato ringspot virus* (ToRSV)	Yes	Yes	High (yield losses of >50% in raspberries recorded)	Yes	No*
	Citrus tristeza virus (CTV)	Yes	Yes	Stunting, chlorosis, stem pitting and reduced fruit growth	Yes (on plants and fruit with leaves and peduncles of *Citrus*, *Fortunella* and *Poncirus*)	Yes*
	Pepino mosaic virus (PepMV)	Yes	Yes	Curling of top leaves, discoloration of fruit	Yes (emergency measures on tomato seeds)	Yes
Bacteria	*Xylella fastidiosa*	Yes	Yes	Depending on hosts, wilting, scorching of foliage, branch dieback, death of plants, reduced fruit size	Yes	No*
	Pseudomonas syringae pv. *actinidiae*	No	Yes	–	No	No*
	Xanthomonas arboricola pv. *corylina*	No	Yes	Death of young plants, buds and fruiting shoots death on older plants	No	No*
	Xanthomonas arboricola pv. *pruni*	No	Yes	Severe defoliation, weakening of trees; fruit often small and unmarketable	Yes (on plants for planting of *Prunus*)	Yes*
	Xanthomonas axonopodis pv. *citri*	Yes	No	Lesions on shoot, leaves, fruit; premature fruit drop, defoliation, reduction of fruit quality	*Xanthomonas campestris* (all strains pathogenic to *Citrus*) is covered	Yes
	Xanthomonas fragariae	Yes	Yes	Symptoms on green parts of the plant, reduction of yield but generally not destructive	Yes (on *Fragaria* plants)	No*
	Xanthomonas perforans	No	Yes	Lesions on stems	Yes (as *X. campestris* pv. *vesicatoria* on plants of *Lycopersicon* and *Capsicum*)	No*
	Acidovorax citrulli	No	Yes	Lesions on fruit, necrotic areas on leaves, seedling blight	No	Yes*
	Erwinia amylovora	Yes	Yes	Dieback of stems, wilting, collapse of the leaves and fruit	Yes (on plants for planting of *Amelanchier, Chaenomeles, Cotoneaster, Crataegus, Cydonia, Eriobotrya, Malus, Mespilus, Photinia davidiana, Pyracantha, Pyrus* and *Sorbus*)	No*

(continued)

Table 1 *(continued)*

Pest group	Species name	Intercepted	Present in EU	Damage[1]	Regulated in EU	Fruit as known or potential pathway[2]
Bacteria *(continued)*	*Erwinia chrysanthemi*	(Yes) (not in the EU, but in EPPO)	Yes	–	No	No*
	Pantoea ananatis	No	Yes	Damage on fruit, leaves or stem depends on hosts, e.g. blotches, streaks, blight, necrosis on leaves; brown rot; stem rot; shoot tip die-back	No	Yes*
	'*Candidatus* Liberibacter solanacearum'	No	Yes	–	No	Yes* (if green parts)
	'*Candidatus* Liberibacter asiaticus'	No	No	Yellowing of leaves, dieback of twigs, premature fruit drop, death of trees	Yes (as Citrus greening bacterium on plants of *Citrus*, *Fortunella* and *Poncirus*)	No*
	Ralstonia solanacearum	Yes	Yes	–	Yes (as *Pseudomonas solanacearum*)	No*
	Grapevine flavescence dorée phytoplasma	Yes	Yes	–	Yes (on plants of *Vitis*)	No*
Unknown risks[3] #	*Aphis illinoiensis*	No	Yes	–	No	Yes*
	Ataenius picinus	No	Yes? (outbreak in Italy)	Larvae attack seedlings and adults roots of strawberries, potatoes and beans, sometimes decaying fruit		No*
	Stelidota geminata	No	Yes	Attacks mature fruit		Yes*
	Carpophilus lugubris	No	Yes	Incidentally feeds on mature fruit; its potential damage to crops is still unknown		Yes*
	Aleuroclava aucubae	No	Yes	–		Yes* (if leaves)
	Aleuroclava psidii	Yes	No	–		Yes
	Paraleyrodes minei	Yes	Yes	Feed on leaves, including on *Citrus*		Yes* (if leaves)
	Trialeurodes abutiloneus	Yes	No	–		Yes*
Tropical fruit pests[3] #	*Diaphania indica*	Yes	No	External feeding on leaves and fruit	No	Yes
	Aulacaspis tubercularis	Yes	Yes? (Italy?)	Significant pest of mango, affects commercial value of fruit, retards growth of plants	No	Yes

(continued)

Table 1 *(continued)*

Pest group	Species name	Intercepted	Present in EU	Damage[1]	Regulated in EU	Fruit as known or potential pathway[2]
Tropical fruit pests *(continued)*	*Cerataphis brasiliensis*	No	Yes	Damage to young plants	No	No*
	Dysmicoccus brevipes	Yes	Yes	Wilting, dieback of stems	No	Yes
	Dysmicoccus neobrevipes	Yes	Yes? (Italy?)	–	No	Yes
	Aleurotrachelus atratus	Yes	Yes	Honeydew production, wilting, drop of leaves	No	No*
Unexpected change of hosts[3] #	*Scirtothrips mangiferae*	No	No	–	No	Yes*
	Cyrtopeltis tenuis	Yes	Yes	Feeds on stems, leaves and flowers of some crops	No	Yes*
	Paracoccus tripurae	Yes	No	–	No	Yes
	Cucumber mosaic virus (CMV) (virus)	No	Yes	Dwarfing, deformation of fruit	No	No*
Fruit pests not likely to be transported on fruit[3] #	*Aphelenchoides fragariae* (Nematoda)	Yes	Yes	Malformation of the shoot, dieback of whole plant	No	No*
	Aphelenchoides besseyi (Nematoda)	Yes	Yes	–	Yes (on plants of *Fragaria* and seeds of *Oryza*)	
	Anoplophora chinensis, A. glabripennis	Yes	Yes	–	Yes	
	Aroma bungii	Yes	Yes	–	No	
	Saperda candida	No	Yes	–	No	
	Phloeotribus liminaris	No	Yes	Weakening of trees	No	
	Pityophthorus juglandis	No	Yes	Leaf wilting, twig and branch dieback, cankers, plant death	No	
	Xyleborus perforans	Yes	No	Wilting, dieback, decline in vigour	No	
'**Hitchhikers**[3]' #	*Blissus diplopterus*	Yes	No	–	No	Yes
	Maruca vitrata	Yes	No			
	Cernuella virgata, Cryptomphalus aspersus (Gastropoda)	Yes	Yes			
	Brachymyrmex obscurior	Yes	Yes	–	No	Yes
	Periplaneta americana	Yes	Yes			
	Syrphophilus bizonarius	Yes	Yes			
	Halyomorpha halys	Yes	Yes	Feeds on leaves, stems and fruit	No	Yes*

Note

1. The damage is not documented for all pests in this review, and the column 'damage' is consequently empty for some pests.
2. The column 'fruit as known or potential pathway' was completed using information on known pathways of international movement (including interceptions), but also potential pathways (based on the biology). Answers based only on consideration of potential pathways are marked with *.
3. All pests in the pest groups marked with # are insects, except where indicated otherwise after the pest name.