

SCIENTIFIC OPINION

Scientific Opinion on the risks to plant health posed by *Bemisia tabaci* species complex and viruses it transmits for the EU territory¹

EFSA Panel on Plant Health (PLH)^{2,3}

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ABSTRACT

The Panel on Plant Health conducted a pest risk assessment for *Bemisia tabaci* and the viruses it transmits, including an evaluation of risk reduction options and an assessment of the effectiveness of the special requirements linked to *B. tabaci* and the viruses listed in Council Directive 2000/29/EC. *B. tabaci* and a large number of viruses transmitted by this polyphagous insect occur in subtropical and tropical climates around the world. Five entry pathways for *B. tabaci* and associated viruses were identified, with the plants for planting pathway being most significant and rated for entry of insects and viruses as likely and moderately likely, respectively. The most invasive *B. tabaci* species and several of its associated viruses responsible for severe diseases in major European food crops are established outdoors in coastal Mediterranean regions. Because of similar climate requirements and host plant preferences, *B. tabaci* and associated viruses currently not present in Europe are likely to establish within the temperature limits set for *B. tabaci*. Trade between European Member States allows *B. tabaci* to reach greenhouses in northern Europe, including those in areas with protected zone status. Because of the cool climate, establishment and spread outdoors of *B. tabaci* is rated unlikely for northern Europe. This situation is likely to continue even under a climatic scenario with an increase in temperature of +2 °C. *B. tabaci*-transmitted viruses cause severe diseases with major negative impact on crop production when risk reduction measures are not used. Risk reduction options will also apply to *B. tabaci* and viruses new to Europe. Risk reductions options are evaluated in terms of reducing *B. tabaci* populations, crop infestations, virus incidence and the impact of diseases. © European Food Safety Authority, 2013

KEY WORDS

Bemisia tabaci, European and non-European *Bemisia tabaci*, begomoviruses, non-circulatively transmitted viruses, pest risk assessment, risk reduction options.

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SUMMARY

Following a request from the European Commission, the Panel on Plant Health was asked to deliver a scientific opinion on the risks posed by *Bemisia tabaci* to plant health in the European Union territory, with particular regard to the viruses it transmits. The Panel was also requested to identify risk management options and to evaluate their effectiveness in reducing the risks to plant health posed by these organisms. In addition, the Panel was asked to provide an opinion on the effectiveness of the present EU special requirements linked to *B. tabaci*, which are listed in Annex IV of Council Directive 2000/29/EC, which aim to reduce the risks of introduction and spread of this pest, and of the viruses it can transmit, into and within the EU territory.

The Panel conducted the risk assessment, the evaluation of identified risk reduction options and the evaluation of the effectiveness of the present EU special requirements linked to *B. tabaci* and the viruses it transmits listed in Annex IV of the Council Directive 2000/29/EC following the general principles of the “Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options” (EFSA Panel on Plant Health (PLH), 2010). The identification of risk reduction options was performed according to the “Guidance on methodology for evaluation of the effectiveness of options for reducing the risk of introduction and spread of organisms harmful to plant health in the EU territory” (EFSA Panel on Plant Health (PLH), 2012).

After consideration of the evidence, the Panel reached the following conclusions:

With regard to the assessment of the risks to plant health:

B. tabaci is considered to be one of the most serious threats to crop cultivation worldwide, predominantly because of the large number of viruses it transmits. In regions where *B. tabaci* is established, viruses transmitted by this insect, especially those affecting tomato and cucurbits, and also beans, pepper and aubergines, are responsible for severe diseases that have a strong negative impact on crop yield. As a consequence, crop production in those areas is not possible without a system-wide and comprehensive set of pest and disease management measures in place. In the risk assessment area, *B. tabaci* is present outdoors in coastal areas with a Mediterranean climate, and in many EU countries the pest is present in greenhouses.

B. tabaci is a complex of at least 28 indistinguishable morphocryptic species, of which four occur in Europe. Two species, Mediterranean (Med, formerly referred to as biotype Q) and Middle East–Asia Minor 1 (MEAM1, formerly referred to as biotype B), are mostly associated with negative effects on crops such as ornamentals, tomato and cucurbits, and are prevalent both in Europe and in many regions across the world. Many other *B. tabaci* species exist outside the risk assessment area, and these can reach high population densities, but it is only Med and MEAM1 that are considered invasive. All *B. tabaci* species can transmit viruses, and the viruses associated with *B. tabaci* reported from around the world have an immense diversity, which is reflected in numerous species and strains. In general, diseases resulting from virus infections have a serious negative impact on crops and, thus, the introduction of *B. tabaci*-transmitted viruses currently not present in the EU would be a significant risk.

ENTRY

For entry of *B. tabaci* and the viruses it transmits, five pathways have been identified, and the most relevant one is the plants for planting pathway. Plants not intended for planting (cut flowers and branches with foliage) and the pathway represented by fruits and vegetables were also considered, while entry of *B. tabaci* through human-associated means not involving plants (e.g. on vehicles or clothes) and entry of insects by natural means (e.g. with wind or active flight) were considered negligible pathways and not assessed in this opinion.

Viruses can enter with infected plant material and with insects carrying the viruses (viruliferous insects). The transmission modes of *B. tabaci*-transmitted viruses are substantially different and have a

strong influence on the probability of entry. Therefore, viruses were grouped into circulatively transmitted viruses (begomoviruses) and non-circulative viruses (all other viruses); these two groups are considered separately in the opinion.

The evaluation of the likelihood of entry of pest and viruses was supported with a probabilistic model that combined expert assessment of the presumed risk of entry from the major world areas with trade volumes of commodities related to the three pathways.

Pathway 1. Plants for planting

- Entry of *B. tabaci* can be expected from all world areas where populations of this insect are established, because *B. tabaci* is not only a polyphagous pest infesting a wide range of plant species (host plants) but can also be carried along on non-hosts, that is with plants on which the insect is only visiting (non-host plants).
- The probability of entry of *B. tabaci* into the EU by the plants for planting pathway is rated as likely, because of the frequent association of insects with the pathway at origin and based on the number of interception records despite strict phytosanitary requirements for places of production of plants for planting. Although the fraction of intercepted consignments relative to the total number of consignments imported into the EU is low, the high trade volumes justify this rating.
- The major volume of trade in this pathway mainly concerns ornamental plants. The specific ornamental plant species that are imported via this pathway are non-host plants for *B. tabaci*-transmitted viruses. Entry of circulatively transmitted viruses can occur with viruliferous *B. tabaci* insects and with infected plants while non-circulatively transmitted viruses can enter only with infected host plants, because of their limited persistence in their vector. Entry of viruses with viruliferous *B. tabaci* or with infected crop plants is considered as moderately likely.

Pathway 2. Cut flowers and branches with foliage

- The probability of entry of *B. tabaci* into the EU with the pathway of cut flowers and branches with foliage is considered as moderately likely because eggs and nymphal stages of the pest can survive transport. The short storage periods and limited vase life of cut flowers reduce the probability of transfer of insects to a suitable host plant. Although the most important cut flower species require phytosanitary inspection and a phytosanitary certificate for import, interceptions still occur and the high volume of trade justifies this rating.
- The entry of circulatively transmitted viruses is bound to viruliferous *B. tabaci* adults. Because survival of adult insects during transport and storage is unlikely, the probability that viruses enter via this pathway is considered unlikely. The probability that non-circulatively transmitted viruses associated with *B. tabaci* enter into the EU with cut flowers is rated as very unlikely as the ornamentals under concern are non-host plants for these viruses.

Pathway 3. Fruits and vegetables including leafy herbs for consumption

- *B. tabaci* may enter the risk assessment area on vegetables, leafy herbs (specific regulations apply only for *Ocimum* spp. and *Apium* spp.) and on fruits with remaining leaves (e.g. tomato vines). The probability of entry of *B. tabaci* into the EU with the pathway fruits and vegetables is estimated as unlikely because of the pathway characteristics (cold chain) and the low probability of transfer to a suitable host after arrival in the EU. Thus commodities intended for consumption are unlikely to present a pathway. This is despite the numbers of specimens intercepted on those commodities. Because leafy herbs imported as live potted plants can have a prolonged vase life, a higher risk is associated with these cases and thus the probability of entry of *B. tabaci* would be moderately likely.

- Virus entry with *B. tabaci* on fruits, vegetables and leafy herbs is considered very unlikely, because many species used as leafy vegetables and herbs (basil) are not susceptible to *B. tabaci*-transmitted viruses. There also is a very low probability that transfer from virus-infected fruits to suitable host plants would occur. Notwithstanding this, in regions where *B. tabaci* is established outdoors, discarded fruits or peel can be sources of infection and pathways of virus entry.

Information on *B. tabaci* interceptions shows that control measures and phytosanitary requirements in the area of production and inspections to prevent insects from entry have limitations. The limited efficacy of inspections at entry and the high volumes of trade attribute a medium uncertainty to the evaluation of the risk of entry of *B. tabaci*. Uncertainty further exists about aquatic plants entering the EU, on which *B. tabaci* is frequently intercepted. This is because it is unclear whether these plants are kept for further propagation or for direct marketing to the end user. Because of dual use, some commodities can be assigned either to pathway 2 or to pathway 3. In the case of some species, e.g. *Eryngium* sp. and *Limnophila aromatica*, high rates of interception were in the past observed on cut flowers, but currently these generate interception reports almost exclusively on vegetables and fruit for consumption. Because cut flowers and branches with foliage are subject to more stringent import requirements and fruits and vegetables for consumption are largely not regulated, such changes in the commodity class further contribute to uncertainties on the ratings of the entry pathways for *B. tabaci*.

For viruses transmitted by *B. tabaci* uncertainty exists whether newly introduced ornamental plant species including aquatic plants can be new host plants for hitherto unknown viruses. However the uncertainties concerning new viruses entering into the EU with any of the pathways can be rated as low.

The application of measures for import consignments which pose a risk seems to be most effective to reduce the probability of entry with all major entry pathways for *B. tabaci*. However interception reports indicate the limitations of the measures.

ESTABLISHMENT

B. tabaci species MEAM1 and Med are established in many parts of the risk assessment area. As there are many host plant species available for these polyphagous pests, outdoor establishment is limited only by climatic conditions. The assessment of *B. tabaci* establishment is supported by the results of a population dynamics model that was developed with biodemographic temperature-dependent functions estimated for *B. tabaci* in which climatic data were used to predict the area of potential establishment of the insect and the viruses it transmits in Europe.

- Assuming similar climatic requirements for all *B. tabaci* species, outdoor establishment of *B. tabaci*, including those species entering the risk assessment area from outside is considered as likely in the areas where *B. tabaci* is already present. Similarly, the climatic conditions for crop production in greenhouses favour *B. tabaci* population development and, as proven by records of outbreaks in greenhouses, *B. tabaci*, once introduced, is likely to establish.
- In crops such as tomato or cucurbits, Med and MEAM1 are well adapted to the intensive production conditions, and newly invading *B. tabaci* species would probably be less competitive in those crops but may establish on other plant species. Because *B. tabaci* Med and MEAM1 are highly invasive species and are present throughout the world, it is likely that insects entering into the EU are MEAM1 and Med, and those would merge with existing populations of the same species.

In Europe, several *B. tabaci*-transmitted viruses are present in regions where the insect is established outdoors. Those causing tomato yellow leaf curl disease (TYLCD) are considered among the most serious plant viruses in crops.

- Because of the availability of suitable host plants and the presence of efficient vectors, viruses transmitted by *B. tabaci* are likely to establish. This assessment concerns viruses infecting tomato and cucurbit crops which are available almost throughout the year in the production areas of the Mediterranean regions (greenhouses and outdoors) and in the greenhouses of northern EU countries.
- New diseases from recently emerging (novel) *B. tabaci*-transmitted viruses mostly recorded on cucurbits and on tomato provide evidence for newly introduced pathogens and indicate ongoing processes of establishment.
- As far as establishment of other *B. tabaci*-transmitted viruses is concerned, their establishment largely depends on suitable host plants available in the environment and serving as reservoirs for survival and new plant infections. The availability of alternative host plants is not an important requirement for viruses infecting tomatoes and cucurbits.
- Newly introduced begomoviruses infecting tomato would likely contribute to TYLCD, establish mixed virus infections, or compete with existing Tomato yellow leaf curl viruses (TYLCV) that are highly adapted to tomato.

Uncertainties concerning the assessment of the outdoor establishment of *B. tabaci* are rated as low, because, according to the population dynamic model, estimates of the area of supposed establishment and the northern limits of expansion can be well defined. *B. tabaci*-transmitted viruses are established outdoors in several EU Member States. Uncertainties concerning the establishment of *B. tabaci* in greenhouses are also rated as low because of controlled climatic conditions favouring population development and growth of this insect.

The uncertainty rating for the establishment of newly introduced viruses, however, is considered as medium because of the limited knowledge of the factors driving epidemics of non-circulatively transmitted viruses.

SPREAD

Spread of *B. tabaci* in the risk assessment area mainly depends on climatic conditions and the intensity of trade between EU countries. Long-distance spread is mostly by transport of *B. tabaci* with plant commodities through trade which also contributes to dissemination of viruses. Spread is rated as moderately likely for *B. tabaci* and the viruses it transmits.

- An expansion of the outdoor area currently invaded by *B. tabaci*, as well as an increase in its population density, is expected only if the average temperatures in Europe increase. However, even considering a climate change scenario with an increase of on average +2 °C, the northern most limit of distribution of *B. tabaci* will expand, but the insect will still not establish outdoors in northern EU countries, including those with protected zone status.
- In the Mediterranean coastal regions, the ample availability of host plants and suitable environmental conditions support the spread of *B. tabaci* and its viruses. Because of the application of control measures, the population densities of *B. tabaci* are kept low, which also results in a lower incidence of virus diseases.
- Spread of *B. tabaci* and its viruses to northern EU countries occurs because of the high volume of inter-EU trade and insufficient measures to prevent spread.

Uncertainties concerning the spread of *B. tabaci* are rated low because the climate factors limiting outdoor expansion are well known and the northern limits of expansion can be well defined. Medium uncertainty is associated with the rating for virus spread because of the paucity of information on the factors driving epidemics of newly introduced viruses and whether new viruses would express biological features resulting in enhanced vector transmission, rate of replication or host range.

Although there are many effective control options available for *B. tabaci* that also reduce virus problems, they cannot prevent establishment and spread of newly arriving *B. tabaci* and its viruses. The application of control measures can reduce but not eliminate the probability of spread.

IMPACT

Serious crop diseases are the consequence of infection with viruses transmitted by *B. tabaci*, and major consequences for crop production are a result of this whitefly spreading the diseases. Appropriate protection measures need to be in place to limit yield losses, and this also includes crops not affected by viruses transmitted by *B. tabaci* (ornamentals) but on which insect populations can develop rapidly. Because new types of diseases can be expected from novel viruses and also because begomoviruses evolve rapidly, frequently undergo recombination and also occur as mixed infections, the introduction of viruses can be associated with more severe disease symptoms. The overall assessment of the consequences and damage is affected only by the uncertainty on additional consequences from the introduction, establishment and spread of both *B. tabaci* and the viruses it transmits, hitherto not present in the risk assessment area. This assessment is associated with a medium level of uncertainty.

The Panel considers that *B. tabaci* and the diseases from viruses transmitted by this insect primarily affect the yield and quality of crops. The Panel is not aware of publications demonstrating serious pest or disease effects on wild plants in cultivated or natural environments. The most commonly expected environmental effects are those resulting from inappropriate pesticide applications. Environmental side effects are considered to be negligible with low uncertainty in the current area of distribution and in the risk assessment area.

With regard to risk reduction options:

According to the background as provided by the European Commission, *B. tabaci* is a regulated harmful organism in the EU. Its regulation makes a distinction between non-European and European populations.

Non-European *B. tabaci* populations are listed in Annex 1, Part A, Section I, of Council Directive 2000/29/EC as “harmful organisms whose introduction into, and spread within, all Member States shall be banned”. Annex IV, Part A, Section I, lists specific import requirements for herbaceous plants for planting and several species of cut flowers and leafy vegetables in connection with non-European *B. tabaci* populations.

The Panel concludes that the current phytosanitary measures mentioned in Council Directive 2000/29/EC provide sufficient options to ensure freedom of commodities from *B. tabaci* to prevent entry and spread into the EU. However, the number of interceptions provides evidence that implementation of appropriate measures does not entirely prevent the entry of the pest. While further risk reduction options in addition to those targeted at treatment of consignments were not identified, improvements concerning the requirements formulated in the Council Directive can be suggested:

1. Considering the broad spectrum of plant species on which *B. tabaci* is intercepted, a specific mention of the woody plant species *Ficus* L. and *Hibiscus* L. is no longer warranted. The list of plants specified in Annex IV, Part A, 45.1 could be extended to plants for planting in general - herbaceous and woody plants – and disregarding their status as host plants for *B. tabaci*. This then covers the long list of plants on which *B. tabaci* can be found and is especially useful when herbaceous and woody plant species cannot be unequivocally be distinguished.
2. Similarly, the list of cut flowers (Annex IV 45.2.) could also be extended to cover the diversity of plant species imported as cut flowers.
3. The list of viruses in Annex IV 46 should be revised and updated also with reference to the EPPO Alert list A1 and A2 in which for e.g. Cowpea mild mottle virus is no longer listed. The relevant harmful viruses transmitted by *B. tabaci* can also include a statement of the genera to which those viruses belong.

4. In Annex IV 45.3 the statement concerning absence of tomato yellow leaf curl virus symptoms could be amended to include all *B. tabaci* transmitted virus species that cause tomato yellow leaf curl disease and which are currently not present in Europe.
5. In Annex IV Part B, 24.1- 24.3 While it is clear that cuttings and plants of *Euphorbia pulcherrima* comprise the largest volume of trade in the EU, similarly to point 1, there is no argument why the requirements for freedom from *B. tabaci* should be limited only to *E. pulcherrima*, *Begonia* or other plant species listed in 24.1- 24.3. This list should/could therefore be amended.
6. Drafting of specifications for generic measures required in Annex IVAI for official inspection, pest free areas and pest free places of production.
7. The action mentioned under point 1 could be supported by asking exporting countries to provide detailed descriptions of the particular measures implemented following the specifications.
8. Development of official protocols for sampling of consignments to specify the sampling procedures, confidence levels, etc.
9. Considering additional requirements for import of tomato fruit such as removal of green parts attached to fruit or issuing of phytosanitary certificates, due to the significant risk of entry of viruses causing tomato yellow leaf curl disease and *B. tabaci* associated with this commodity.

European *B. tabaci* populations are listed in Annex I, Part B, as “harmful organisms whose introduction into, and spread within, certain protected zones shall be banned”. Annex IV, Parts A and B, outlines specific requirements for the internal movement of certain plants in connection with *B. tabaci* and the viruses it transmits. The Panel concludes that the current phytosanitary measures mentioned in Council Directive 2000/29/EC theoretically provide sufficient options to ensure the freedom of commodities from *B. tabaci* and the viruses it transmits to prevent spread within the EU, and, in particular, that maintaining pest-free areas seems appropriate to achieve this goal. However, implementation of the required measures is not sufficient in some countries/areas, which can be concluded from the number of interceptions from trade within the EU (74 % of all records are on plants for planting). The Panel has identified several additional methods to limit or prevent spread within the EU of *B. tabaci* and the viruses it transmits. Those concern:

1. the use of host plant resistance to *B. tabaci* and/or its viruses,
2. the use of greenhouses, screenhouses, and cages, and
3. the use of control methods summarized by the Panel which are not specifically mentioned in the current Council Directive 2000/29/EC (these methods might constitute important new elements for managing *B. tabaci* and its viruses).

The Panel has not identified additional risk reduction options for the eradication of *B. tabaci* and the viruses it transmits, although application of several of the many control methods for treatment of the crop, field or place of production will result in a reduction in density of *B. tabaci* populations and a reduced transmission and spread of viruses, with a subsequent lower impact on crops.

Finally, the Panel concludes that there are many effective risk reduction options available to prevent the introduction and establishment of *B. tabaci* and the viruses it transmits into the EU, and to prevent the spread of *B. tabaci* within the EU. The Panel stresses that only the combination of risk reduction options and the consequent pursuit of a comprehensive crop management regime will result in the sustainable management of *B. tabaci* and the viruses it transmits.

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BACKGROUND AS PROVIDED BY EUROPEAN COMMISSION

The current European Union plant health regime is established by Council Directive 2000/29/EC on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community (OJ L 169, 10.7.2000, p.1).

The Directive lays down, amongst others, the technical phytosanitary provisions to be met by plants and plant products and the control checks to be carried out at the place of origin on plants and plant products destined for the Union or to be moved within the Union, the list of harmful organisms whose introduction into or spread within the Union is prohibited and the control measures to be carried out at the outer border of the Union on arrival of plants and plant products.

Bemisia tabaci (Gennadius, 1889), the tobacco/cotton whitefly, is a highly polyphagous plant sap-sucking insect (Order: Hemiptera; Family: Aleyrodidae). *B. tabaci* poses a substantial threat to both field and protected agricultural crops and ornamental plants. Damage to plants is caused by the direct feeding activity of the insect, leading to reduced host vigour, growth and yield, chlorosis, uneven ripening and physiological disorders. Mould growing on the honeydew produced by nymphs can cause a reduction of the photosynthetic capability of the plant, resulting in defoliation and stunting. In addition, *B. tabaci* can transmit over 100 plant viruses, which can cause substantial crop yield losses. A large number of those viruses are not known to be present in the EU.

B. tabaci supposedly originated in India but is now distributed nearly worldwide. It is assumed that the international trade of plants infested with whiteflies is responsible for their spread throughout the world. *B. tabaci* is known to be present in parts of the EU territory.

B. tabaci is a regulated harmful organism in the European Union. Its regulation makes a distinction between non-European and European populations. Non-European *B. tabaci* populations are listed in Annex 1, Part A, Section I of Council Directive 2000/29/EC as "harmful organisms whose introduction into, and spread within, all Member States shall be banned". European *B. tabaci* populations are listed in Annex I, Part B as "harmful organisms whose introduction into, and spread within, certain protected zones shall be banned". Presently the whole territory of Ireland, United Kingdom, Sweden and Finland, and defined parts of the territory of Portugal, are recognised as protected zones for *B. tabaci*. Annex IV, Part A, Section I lists specific import requirements for certain plants in connection with non-European *B. tabaci* populations. Annex IV, Part A, Section II outlines specific requirements for the internal movement of plants of *Lycopersicon lycopersicum* (Tomato, *Solanum lycopersicum*) in connection with *B. tabaci* and the tomato yellow leaf curl virus. Annex IVB includes specific requirements for the movements of certain plant into and within protected zones for European *B. tabaci* populations.

Viruses transmitted by *B. tabaci* are listed in Annex I, Part A, Section 1 of Council Directive 2000/29/EC as "harmful organisms whose introduction into, and spread within, all Member States shall be banned". Annex IV, Part A, Section I lists specific import requirements for certain plants in connection with these viruses, which differ depending on the presence or absence of *B. tabaci* or other vectors at the place of origin. In spite of the present import requirements against *B. tabaci*, the insect is often intercepted during import inspections. In order to carry out an evaluation of the present EU requirements against *B. tabaci* and the viruses it can transmit. A pest risk analysis covering the whole territory of the EU is needed, which takes into account the latest scientific and technical knowledge for this organism and its present distribution in the EU.

TERMS OF REFERENCE AS PROVIDED BY EUROPEAN COMMISSION

EFSA is requested, pursuant to Article 29(1) and Article 22(5) of Regulation (EC) No 178/2002, to provide a pest risk assessment of *B. tabaci* Gennadius with particular regard to the viruses it transmits, to identify risk management options and to evaluate their effectiveness in reducing the risk to plant health posed by these organisms. The area to be covered by the requested pest risk assessment is the EU territory. EFSA is also requested to provide an opinion on the effectiveness of the present EU special requirements linked to *B. tabaci*, which are listed in Annex IV of Council Directive 2000/29/EC, in reducing the risk of introduction of this pest, and of the viruses it can transmit, into, and the spread within the EU territory.

ASSESSMENT

1. Introduction

1.1. Purpose

This document presents a pest risk assessment for the territory of the European Union (hereinafter referred to as the EU) prepared by the Panel on Plant Health for *B. tabaci* Gennadius in response to a request from the European Commission. This risk assessment in particular considers the harmful plant viruses transmitted by this insect that present serious threats to the cultivation of major horticultural crops in Europe. The opinion includes the identification and evaluation of the risk management options in terms of their effectiveness in reducing the risk to plant health posed by these organisms and evaluation of the effectiveness of the present EU special requirements linked to *B. tabaci*, which are listed in Annex IV of Council Directive 2000/29/EC,⁴ in reducing the risk of the introduction of this pest, and of the viruses it can transmit, into and spread within the EU territory.

1.2. Scope

The scope of the opinion is to assess the risk from *B. tabaci* and the viruses it transmits taking mainly into account the main host plants cultivated in the risk assessment area, such as tomato, *Solanum lycopersicum* (Solanaceae), some species of cucurbits (Cucurbitaceae) and ornamentals. A detailed assessment of the impacts of *B. tabaci* and the viruses it transmits on plants other than tomato, cucurbits and ornamentals is not included in this document. Nevertheless, as potential host plants for *B. tabaci* and some of the viruses it transmits, the other host plants are examined for their role in pathways for entry and spread.

2. Methodology and data

2.1. Methodology

2.1.1. The guidance documents

The risk assessment has been conducted in line with the principles described in the document “Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA” (EFSA Panel on Plant Health (PLH), 2010). The EFSA adapted European and Mediterranean Plant Protection Organization (EPPO) scheme to conduct a risk assessment, as presented in the Guidance document was used as a checklist to ensure that every question related to the assessment has been answered.

The identification of risk reduction options was performed according to the “Guidance on methodology for evaluation of the effectiveness of options for reducing the risk of introduction and spread of organisms harmful to plant health in the EU territory” (EFSA Panel on Plant Health (PLH), 2012). The Panel identified potential risk reduction options according to the 18 categories described in that guidance. According to the guidance the term “risk reduction option” is used instead of risk management option. The Panel evaluated all identified risk reduction options in line with the “Guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options by EFSA” (EFSA Panel on Plant Health (PLH), 2010).

⁴ Council Directive 2000/29/EC of 8 May 2000 on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. Official Journal of the European Communities L 169/1, 10.7.2000, pp. 1–112.

2.1.2. Methods used for conducting the risk assessment

The Panel conducted the risk assessment with the current EU plant health legislation in place considering non-European and European *B. tabaci* populations and the viruses they transmit as specified in Council Directive 2000/29/EC (see Section 3.1.9. Regulatory status).

The assessment of the probability of entry was conducted with regard to entry of *B. tabaci* from Third Countries into the risk assessment (RA) area, whereas the assessment of the probability of spread was conducted with regard to further spread of *B. tabaci* within and between EU Member States. Special consideration is given to the protected zones for *B. tabaci* (Ireland, United Kingdom, Sweden, Finland and parts of Portugal) as indicated in Annex I Part B of Council Directive 2000/29/EC.

Similarly, viruses transmitted by *B. tabaci* listed in Annex I, Part A, Section I of Council Directive 2000/29/EC and the regulation of the internal movement of plants of *S. lycopersicum* in connection with *B. tabaci* and the tomato yellow leaf curl virus (TYLCV) (Annex IV, Part A, Section II) were taken into account. Specific import requirements of certain plants with respect to viruses (Annex IV Part A section I) including specific requirements for the movements of certain plants into and within protected zones for European *B. tabaci* populations (Annex IV Part A section I) were considered as well. The conclusions for entry, establishment, spread and impact are presented separately.

2.1.3. Modelling

A mathematical modelling framework has been developed to support the risk assessment process. Expert opinion and trade data were incorporated into a probabilistic model to estimate the arrival of *B. tabaci* and the arrival of the viruses transmitted by this insect. A physiologically based demographic model has been used to describe *B. tabaci* population dynamics depending on temperature. The population dynamics model provides an indication of the areas where *B. tabaci* may potentially establish and defines the areas where the associated viruses may putatively establish.

The process of arrival is complex and requires the consideration of heterogeneous elements (e.g. the range of host plants, the areas of origin and the processes of entry). In many cases a lack of data prevents a straightforward modelling approach for the entire pathway analysis. The procedure of eliciting subjective experts' knowledge could be used to advantage if the complex process of arrival can be subdivided into a subset of simpler processes and relatively more homogeneous elements. Reducing the heterogeneity and complexity of the process makes it easier to link subjective estimations with available data or information supporting the expert opinion.

To make possible a detailed analysis of the processes involved in arrival, the experts' knowledge elicitation procedure needs to be supported by tools able to (i) combine data and observations with subjective evaluations, and (ii) put together the transition probabilities of the single phases of the arrival process. For this purpose a probabilistic model for the estimation of the probability of arrival was developed and applied to the estimation of the probability of arrival of *B. tabaci* and the viruses it transmits.

The probabilistic model allows weighting of the subjective expert evaluations with objective information to obtain more reliable estimates of the probabilities of arrival. The approach was based on a detailed questionnaire supporting the expert assessment at a high level of resolution in terms of the processes and the category of elements (commodity and area of origin) considered. The experts were asked to provide probability distributions for each process involved in the arrival of different commodities and macro-areas of origin. Factual information (trade data, presence/absence of *B. tabaci* and the viruses it transmits) was merged with subjective probability and "biased" assessment.

The process of the arrival of *B. tabaci* comprises different phases (Figure 1). At the end of this process, populations of *B. tabaci*, including those new to the RA area, are introduced. Viruses enter the RA area by means of virulent *B. tabaci* or with infected host plants. The transition probabilities

between the different phases of the arrival process were assessed during an expert knowledge elicitation procedure. The probabilities estimated were then combined with trade volume data of commodities potentially carrying *B. tabaci* and viruses, to estimate the probability of arrival of *B. tabaci* and of viruses (see Appendix C, Tables C.4, C.5 and C.6).

It is worth noting that the transition probabilities between different phases were provided for each macro-area and for different commodities. This allowed the combination of the subjective probability of the arrival of *B. tabaci*, or of a new virus, with the corresponding trade volume. Using the formulae reported in Appendix E, it was possible to bring together all probabilities for different macro-areas and to obtain the probabilities of arrival in the EU (or in each EU Member States (MS)). In particular, a probability distribution for arrival was obtained. This also allowed calculation of the standard deviation of the arrival distribution (reported in Appendix E), which provides an indication of the level of uncertainty associated with the arrival process.

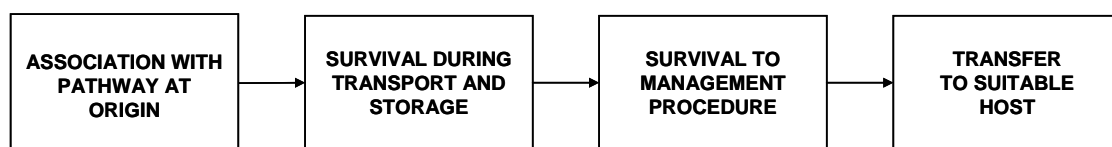


Figure 1: The phases of the arrival process

Once they have entered an area *B. tabaci* and its associated viruses can establish and spread following the series of processes summarised in Figure 2. To estimate the area of potential establishment of *B. tabaci*, a physiologically based demographic model was developed. This model describes the temperature-dependent *B. tabaci* population dynamics and defines the area of potential establishment by also providing an indication on the potential area of virus establishment. It was also used to predict spread under specific climatic change scenarios.

2.1.3.1. Mathematical model to estimate the probability of arrival of *B. tabaci* and the viruses it transmits

To estimate the probability of arrival, different models for *B. tabaci* and associated viruses were considered. The modelling structure and analysis are briefly introduced below with details provided in Appendix E. Because of the lack of accurate data, a quantitative pathway model was considered to be impossible to develop. This is because information on *B. tabaci*, its association with the pathway at origin, survival during entry stages and, subsequently, transfer of insects to suitable hosts, is inconsistent and comprises uncertainty. Furthermore, interception data also do not provide real estimates of the magnitude of entry of the pest. Therefore, for quantitative risk assessment, expert opinion was solicited in a detailed questionnaire to estimate the probabilities of arrival and transition in the different phases (Figure 1). The questionnaire was answered by members of the working group. Estimates were made considering the three main pathways of entry identified for *B. tabaci* and associated viruses (see Section 3.2 and Appendix C, Tables C.4, C.5 and C.6) arriving from nine geographic macro-areas. This provided a general estimate of the probability distribution (see Appendix E) of each process leading to arrival (Figure 1). The probability of arrival of *B. tabaci* was then calculated using a formula combining the probability distributions of the arrival process and the trade volumes of different types of commodities (see Appendix E, Section 1.1).

An approach similar to that for *B. tabaci* was used to calculate the probability of arrival of viruses transmitted by *B. tabaci*. Viruses can enter into the RA area with viruliferous *B. tabaci* or with infected host plants. Because of differences in persistence in the insect vector, viruses that are transmitted in a circulative transmission mode (CVs) and non-circulatively transmitted viruses (NVs) were considered separately (Appendix E).

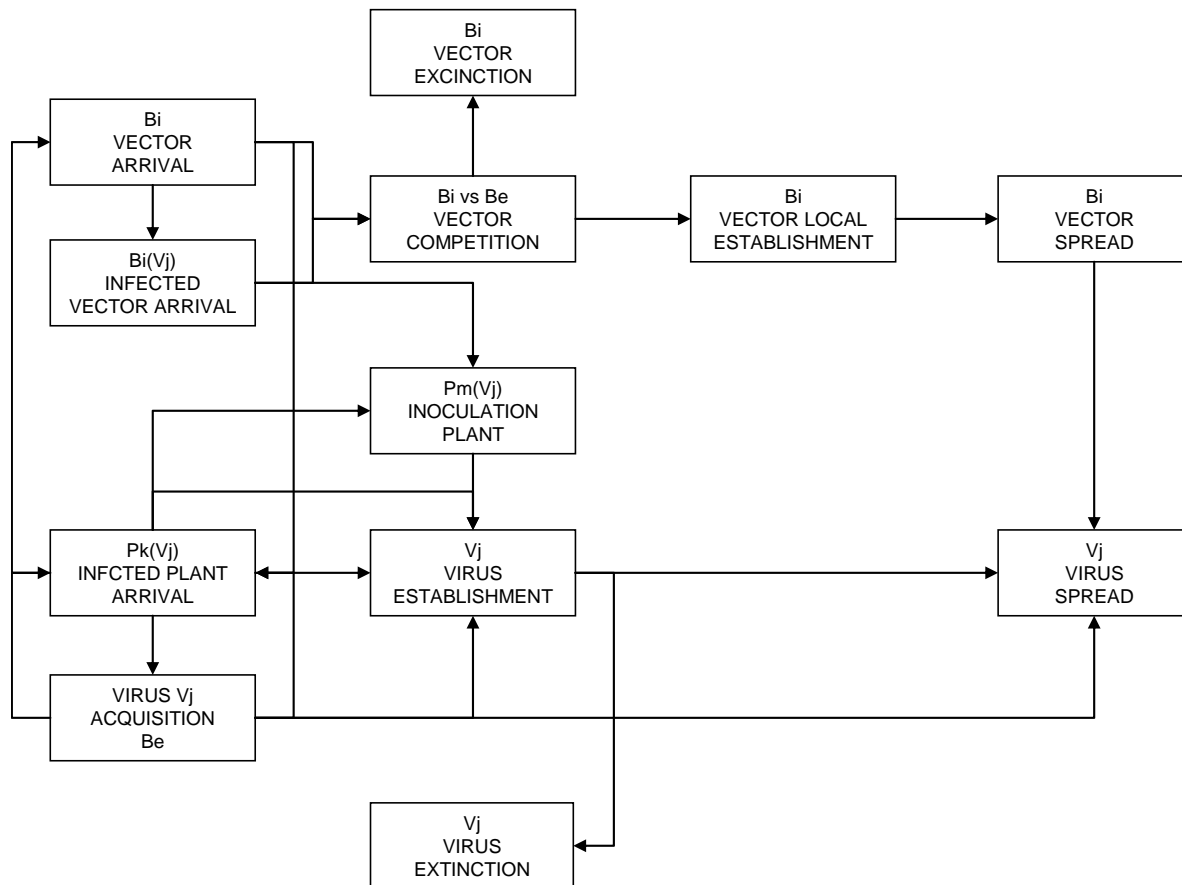


Figure 2: Simplified processes following the arrival of *B. tabaci* (Bi) and virus (Vj) resulting in establishment and spread of *B. tabaci* and the viruses it transmits. “Be” represents the *B. tabaci* species already established in Europe; Pk(Vj) represents the commodity k carrying the virus Vj; and Pm(Vj) represents a host plant inoculated by the virus Vj

2.1.3.2. Population dynamics model to describe establishment of *B. tabaci*

Methods generally used to predict the geographic distribution of species are classed as ecological niche models (ENMs) that attempt to characterise the ecological niche of a species based on weather and other factors in the species' native range. This then is used to estimate the potential invasiveness of the species in new areas. The methods include statistical models (e.g. GARP), physiological indexes (e.g. CLIMEX), artificial intelligence (e.g., MaxEnt) and other approaches (Elith and Leathwick, 2009; Gutierrez et al. 2010).

However, because the prediction of the potential of establishment of invasive species is foremost an exercise in applied population ecology, holistic weather-driven physiologically-based demographic models (PBDM, Curry and Feldman, 1987; Metz and Diekmann, 1989; Gutierrez, 1996; Di Cola et al., 1999) for single species and multi-trophic systems are better suited. Applying PBDM can explain population processes from life-history traits described at an individual level. PBDMs are transparent and change in population abundance can be mathematically described in terms of variation in basic demographic processes and not as a result of intergrating independent or correlated variables. Population dynamics is the outcome of the three fundamental demographic processes development, mortality and fecundity while other processes, for example movement, can also be included.

With PBDM it can be assessed how the physiology of an invasive species is conditioned by both biotic and abiotic environmental variables. Biophysical and bottom-up approaches translate into the definition of continuous rate functions describing development, survival and fecundity as a function of environmental variables and resources. Because of the temperature dependency of biophysical processes, temperature is generally considered as the most important environmental force.

PBDMs are based on well accepted models in mathematical ecology. In most cases a limited set of formulae can describe biodemographic functions. These are well known (a minimum dataset is available for most pests) and can be estimated from laboratory experiments therefore and are widely adopted in applied population ecology. PBDMs also allow sources of variability and uncertainty to be considered and quantified (Di Cola et al., 1999; Braumann, 2008).

The PLH Panel decided to use this innovative approach in order to explore its potentiality for the PRA of *Bemisia tabaci* species complex and the virus it transmits.

To estimate the climatic niche sufficiently well and to analyse the distribution and relative abundance of invasive species, a modest amount of accurate biological data is required to formulate these models (Gutierrez et al., 2010; Gutierrez and Ponti, 2012).

In a first approximation, disregarding the bottom-up effects of the hosts and the top-down effects of higher trophic levels it is possible to obtain models through an estimation of development rates, mortality and fecundity as temperature-dependent rates functions. As for many invasive species, these biodemographic functions can also be estimated for *B. tabaci*. The main advantage of this approach is the possibility of (i) analysing the population responses to climate and integrating the responses of the biodemographic traits to temperature, (ii) using the abundance as a state variable allowing the analysis of the spatial variation of the expected population abundance (with implications also for the assessment of the potential impact of the invasive species), (iii) interpreting in a mechanistic way the variation in the population dynamics with the change in the environmental forcing variable.

Life history traits for *B. tabaci* were compiled from the available literature (see Appendix E2), restricting data to reports also specifying the *B. tabaci* species (formerly known as biotypes B or Q) used in the respective study. For the MEAM1 species (formerly reported as biotype B) the number of eggs laid per female was generally higher than for Med species (biotype Q), while development and mortality rates were very similar for the two species. Because significantly more literature references were available for MEAM1 species, only data obtained for this species were included in the simulations. Based on its biodemographic performances we considered that this *B. tabaci* MEAM1 species (biotype B) has prospectively a wider area of potential establishment and reaches on average higher population abundance. The fact that the Med species could take advantage of its resistance to pesticides does not affect the projection on potential establishment as a function of climate suitability.

A lattice model was used to describe *B. tabaci* population dynamics using a grid of 25 × 25 km for Europe. Biodemographic temperature-dependent rates functions were estimated using data from the literature on *B. tabaci*. Stage-structured population dynamics for *B. tabaci* were simulated, in each point of the spatial grid, following a demographic model obtained through a discretisation of the von Foerster equation (Di Cola et al., 1999). The model simulates an entire year of *B. tabaci* population dynamics using a time step of one hour (a small time interval is required to guarantee the convergence of the discretised von Foerster equation). The model used climate data from the WorldClim database (University of California at Berkeley) for 1950–2000 temperature data, with spatial resolutions according to the climate data (WorldClim, online). The climate data calculated on such a long reference period expresses a robust average temperature input for the model, providing the mean monthly temperature over the last 50 years. Maximum and minimum monthly temperatures were obtained for each node of the grid. Subsequently an interpolation model considering geographic position and astronomic data was used to obtain the hourly temperatures at each node.

The state variable is the population abundance $N_{ij}(t)$ in each stage i on the node j at time t . From $N_{ij}(t)$ the following indexes were derived:

- *BP*, which is an index of population presence, defined as the fraction of the time in a year in which the number of adults per plant is above a given threshold (see Appendix E)
- *BA* which is an index of the population pressure defined as the average number of adult per plant per time unit calculated in the period of the year in which the abundance is above the threshold defined for *BP*.

The demographic model represents the reactions of the organisms to temperature. The estimation of a continuous distribution of the temperature-dependent biodemographic functions allows a detailed assessment of the responses of populations to the local climate (i.e. the node in the simulation grid). Model simulation produces dynamics of abundance of *B. tabaci* in each node of the grid. The area of potential establishment as well as the northern limits of *B. tabaci* distribution (in nature) can thus be determined. From estimation of the demographic performance of *B. tabaci* in Europe, requirements of new species to establish to displace existing ones can also be deduced (i.e., invisibility analysis).

For validation of the population dynamics model, the *B. tabaci* distribution predicted under the current climatic situation was mapped to *B. tabaci* findings in open fields in Europe.

2.1.3.3. Mathematical model to estimate the probability of establishment of *B. tabaci*-transmitted viruses

For viruses transmitted by *B. tabaci*, only a risk map for virus establishment can be drawn because infection pressure and point of virus entry (arrival) are not known. Virus infections are maintained in susceptible plants generally as long as the plant is living. However, for the virus population to continue, spread to other host plants is a prerequisite. Because most of the host plants for whitefly-transmitted viruses are not perennial, new infections occur only when *B. tabaci* is present. Consequently, when suitable host plants (crops and wild plants as virus reservoirs) in the RA area are not limiting factors, virus establishment follows the spread of *B. tabaci*, and this depends on the presence (throughout the year) and abundance of *B. tabaci* (individuals per plant).

Therefore, the probability of establishment is computed as function of the indexes *BP* and *BA*, as defined above, in each node of the simulation grid in the current climatic situation. The result is a map on a grid 25 × 25 km of putative virus establishment in Europe.

2.1.3.4. Exploration of climatic scenarios

Climate scenarios generally consider changes in temperature for a time horizon far beyond that of the RA analysis. For the purpose of this RA a time horizon of 20 years was set. Projections on temperature changes, based on the Global Climate Model (GCM) are subject to uncertainty. This uncertainty is low on a global scale, but on a continental or lower scale errors increase (Koutsoyiannis et al., 2008). This strongly affects the reliability of scenarios on future spatial and temporal patterns of temperature for the purpose of analysing the response of *B. tabaci* population dynamics to temperature change.

The sensitivity analysis of *B. tabaci* population dynamics to temperature change performed here is based on a different approach that uses systematic perturbation of current climate average. A +2° C temperature perturbation is considered. For further details and justification for the approach, see Appendix E.

2.1.3.5. Uncertainty affecting the modelling approaches

The results of the model developed to estimate the probability of the arrival of *B. tabaci* and the viruses it transmits are affected by the subjective judgement inherent in expert elicitations in which

factual information (presence/absence of *B. tabaci* and the viruses it transmits) is merged with perception and “biased” assessment. In addition, trade data from EUROSTAT and FAOSTAT used for quantification of the probability of entry are highly condensed and these bulked measures bear a high level of uncertainty. The unavailability of highly detailed data on trade volume (e.g. at single plant species level per macro-area) introduces an incommensurable error that leads to uncertainty in the model output.

The population dynamics model is affected by uncertainties about the potential establishment of *B. tabaci* and the viruses it transmits. These are uncertainties associated with the estimation of biodemographic functions and those concerning climatic change. The uncertainty concerning biodemographic functions has been assessed considering a stochastic extension of the demographic model of *B. tabaci*. In the stochastic model confidence bands for the biodemographic functions were introduced and correlated to the variability of the experiments performed to estimate temperature-dependent development, mortality and fecundity rates. A large number of simulations of population dynamics were performed that further demonstrated that only minor variations were innate to the population dynamics, moreover confirming the distribution of areas remaining pest free. Thus the main source of uncertainty would be related to the climate change scenario. By assuming a worst-case scenario, the necessity of performing a sensitivity analysis of the model output to climate change was avoided.

2.1.4. Methods used for evaluating the risk reduction options

The Panel identified potential risk reduction options (RROs) by using the classification of RROs presented in the EFSA guidance document on the methodology for evaluation of the effectiveness of options to reduce the risk of the introduction and spread of organisms harmful to plant health in the EU territory (EFSA, Panel on Plant health (PLH) 2012) and evaluated them with respect to their effectiveness and technical feasibility. The descriptors used to assign qualitative ratings for the evaluation of the effectiveness and technical feasibility of management options are shown in Appendix G.

2.1.5. Level of uncertainty

The levels of uncertainty have been rated separately for the risk assessment conclusions on entry, establishment, spread and impact and for the evaluation of the effectiveness of the management options.

2.2. Data

Literature cited in this opinion was retrieved primarily from specific searches and data collection carried out by the Working Group members who have developed this opinion. Further references and information were obtained from experts. The sources of all data used for this opinion are listed in References.

The evidence considered by the Panel in its assessment was obtained from:

- 1) Scientific papers and reports. Specific searches have been performed on *B. tabaci* and *B. tabaci*-transmitted viruses for relevant information regarding:
 - (a) the damage caused by the pest and the viruses to European crops;
 - (b) the RRO used to control the pest and virus disease;
 - (c) the distribution of *B. tabaci* and the viruses transmitted by *B. tabaci* in the 27 EU MSs.

The specific search was performed using public databases, Thomson Reuters Web of knowledge, PubMed, Google Scholar and SCOPUS, and specific keywords. The retrieved papers were then evaluated based on their relevance for the opinion for the topics specified above.

- 2) Expert knowledge in the field. When expert judgement and/or personal communication were used, justification and evidence are provided to support the statements. Personal communications have been considered only when in written form and supported by evidence and when other sources of information were not publicly available.
- 3) Databases. For the evaluation of the probability of entry and spread of the organism in the EU, the EUROSTAT and FAOSTAT databases were consulted in order to obtain information on trade movements within the EU for the relevant pathways. For the evaluation of the probability of entry, the EUROPHYT database was consulted, searching for pest-specific and/or host-specific notifications on interceptions, as well as non-compliance data. EUROPHYT is a web-based network launched by the Directorate General for Health and Consumers, and is a sub-project of PHYSAN (Phytosanitary Controls) specifically concerned with plant health information. The EUROPHYT database manages notifications of interceptions of plants or plant products that do not comply with EU legislation.
- 4) Questionnaire sent to the national plant protection organisations (NPPOs) of the 27 EU MSs. The EFSA Plant Health Unit developed a questionnaire in MS Excel format and sent it to representatives of the NPPOs of the 27 EU MSs. The aim of this request to the MSs was to confirm the pest status and determine the experience of measures taken against these pests and viruses in the EU territory to enable the Panel to provide advice based on the updated status of these viruses in the EU Member States.

3. Pest risk assessment

3.1. Pest categorisation

3.1.1. *B. tabaci* identity

Bemisia tabaci (Hemiptera: Aleyrodidae), commonly named the tobacco whitefly or the sweet potato whitefly, was first described on tobacco from Greece by Gennadius in 1889 (Tay et al., 2012). It is a cosmopolitan, highly polyphagous (i.e. over 1 000 host plants; see Section 3.1.4 and Appendix B), phloem-feeding insect belonging to a group of insects commonly known as whiteflies.

B. tabaci is a small insect, about 1 mm long for females and 0.8 mm for males, with a white to light yellow body covered in a waxy powdery material. *B. tabaci* is arrhenotokous: unfertilised eggs give rise to haploid males while fertilised eggs develop into diploid females. *B. tabaci* adults develop from eggs, after passing through four nymphal instars. White eggs, which gradually turn brown, are usually laid in semi-circular arrangement on the underside of leaves. Once hatched, the first nymphal instars, or “crawlers”, are capable of only limited displacement and usually move a few centimetres in search of a feeding site. They initiate feeding on the lower surface of leaves and moult throughout the second and third nymphal instar to the fourth, which stops feeding. The nymphs secrete a waxy material at the margins of their body that helps them to adhere to the leaf surface. Development can occur at temperatures between 10 °C and 35 °C, with an optimum between 25 °C and 27 °C. Depending on the prevailing temperatures, development from egg to adult lasts between 15 and 70 days. The lifespan of an adult can extend up to 105 days (Wang and Tsai, 1996, in Dalmon, 2007; Appendix B). *B. tabaci* is multivoltine (more than one generation per year), and a female can lay an average of 80 eggs during her lifetime (De Barro, 1995; EPPO/CABI, 1996; Dalmon, 2007; DAISIE, 2009; Appendix B).

3.1.2. Systematic and taxonomic position

The nomenclature of *B. tabaci* has significantly changed over time, as described in detail by Perring (2001). *B. tabaci* has long been considered by some authors as a complex species composed of many biotypes (similar to races) and by others as a species complex. Its taxonomic status has consequently been, and still is, subject to intensive debate (Brown et al., 1995a; Perring 2001; De Barro et al.,

2011). The distinction of *B. tabaci* into races was first applied in the late 1950s to discriminate two whitefly populations differing in their host plants and viruses transmitted (Brown et al., 1995a). The biotype concept for *B. tabaci* then emerged in the mid-1980s with the supposed first invasion of the southern United States by a new population of *B. tabaci* that induced silverleafing in *Cucurbita* spp., the squash silverleaf (SSL) disorder (Brown et al., 1995a). This *B. tabaci* was called biotype B, to discriminate it from the existing biotype which was called *B. tabaci* biotype A. *B. tabaci* populations characterised by life history traits, host range, insecticide resistance, virus transmission capabilities, physiological alteration induced in plants and association with endosymbionts were subsequently designated as *B. tabaci* biotypes, for which 36 (A to T with subdivisions) are now described (Perring, 2001; De Barro et al., 2011; Liu et al., 2007, 2012a; Table 1). This biotype affiliation was often supported by biochemical (esterases) and/or molecular marker (internal transcribed spacer (ITS) regions, mitochondrial cytochrome oxidase subunit 1 (mtCOI)) differentiation analyses (Costa and Brown, 1991; Burban et al., 1992; Bedford et al., 1994; Perring, 2001; Gueguen et al., 2010; De Barro et al., 2011; Thierry et al., 2011; Tsagkarakou et al., 2012).

A recent global study based on mtCOI sequences of *B. tabaci* from all over the world (Boykin et al., 2007; Dinsdale et al., 2010; De Barro et al., 2011) indicated that *B. tabaci* is composed of 11 well-defined genetic groups comprising distinct *B. tabaci* species differing by genetic divergence values that are consistent with species boundaries. The number of *B. tabaci* species described is increasing with the intensification of whitefly research. While Dinsdale et al. (2010) and De Barro et al. (2011) reported at least 24 species, 28 distinct *B. tabaci* species were defined by Hu et al. (2011) (Table 1). Recently the list of species reached 34, with the addition of species described from Argentina (Alemandri et al., 2012).

The molecular classification supporting *B. tabaci* as a species complex was then corroborated by mating studies which revealed that a number of delineated species were sexually incompatible (Elbaz et al., 2010; Xu et al., 2010, Sun et al., 2010; Wang et al., 2010, 2011).

Table 1: Genetic groups, species of the whitefly *B. tabaci* complex and the biotype designation formerly associated

Genetic group	Species (*)	Associated biotype designations
Africa/Middle East/Asia Minor	Mediterranean (Med)	Q, J, L, Sub-Saharan Africa Silverleafing
	Middle East-Asia Minor 1 (MEAM1)	B, B2
	Middle East-Asia Minor 2	
	Indian Ocean	MS
New World	New World	A, BR, C, D, F, Jatropha, N, R, Sida
Uganda	Uganda	
Sub-Saharan Africa	Sub-Saharan Africa 1	
	Sub-Saharan Africa 2 (SSA2)	S
	Sub-Saharan Africa 3	
	Sub-Saharan Africa 4	
Italy	Italy	T
Asia II India	Asia II 8	
Asia II	Asia II 1	K, P, PCG-1, PK1, SY, ZHJ2
	Asia II 2	
	Asia II 3	ZHJ1
	Asia II 4	
	Asia II 5	G
	Asia II 6	

	Asia II 7	Cv
	Asia II 9	
	Asia II 10	
Asia III	Asia III	
China	China 1	ZHJ3
	China 2	
	China 3	
Australia	Australia	AN
Australia/Indonesia	Australia/Indonesia	
Asia I	Asia I	H, M, NA, PCG-2

Notes: The genetic groups are listed in the order provided by the phylogenetic trees in Dinsdale et al. (2010), De Barro et al. (2011), Hu et al. (2011) and the review of Liu et al. (2012b)

(* abbreviations used in this opinion)

In bold, species and former biotypes designated recorded in Europe

Although the concept of *B. tabaci* as a complex of species is now widely accepted, the term biotype remains vernacular and is still used in the literature. Notwithstanding this, the Panel decided to follow the now accepted classification and regards *B. tabaci* as a species complex. Although the revision of the taxonomy is still an ongoing process, the current nomenclature as summarised in Table 1 will be used in this opinion. Species names are used, with the main references being to the MEAM1 species, formerly referred to as biotype B, and to the Med species, formerly referred to as biotype Q (Table 1). When the term *B. tabaci* is used in this opinion, it refers to *B. tabaci sensu lato*, that is the entirety of *B. tabaci* without distinction between species.

3.1.3. *B. tabaci* species discrimination

B. tabaci is a complex of at least 28 morphologically indistinguishable (morphocryptic) species. Whitefly taxonomy has generally relied on the morphology of the fourth instar (Martin et al., 2000), which, however, in the case of *B. tabaci* shows seasonal differences and variations related to the host plant, affecting both nymphal and adult instars (Bedford et al., 1994; Rosell et al., 1997; EPPO, 2004). In addition, biological characteristics—host range, host reaction (silverleafing), begomovirus transmission, etc.—formerly used to assign *B. tabaci* biotypes are of limited value because they are not consistent either for comparison or to unequivocally and quantitatively assign *B. tabaci* species (De Barro et al., 2011). Therefore, the currently accepted and most widely used method to identify and discriminate among *B. tabaci* species is based on the analysis of mtCOI sequences (Dinsdale et al., 2010; Boykin et al., 2012).

3.1.4. Host range of *B. tabaci*

B. tabaci is considered to be a polyphagous insect with a continuously expanding list of host plants, currently comprising more than 1 000 plant species (Appendix B). Of the six hundred host plant species described for *B. tabaci* by Oliveira et al. (2001) 50 % belonged to five families (Fabaceae, Asteraceae, Malvaceae, Solanaceae and Euphorbiaceae), comprising a large number of cultivated and non-cultivated annual and perennial plants, including economically important plants (i.e. beans, tomato, cucurbits, poinsettia and many more). Because *B. tabaci* can be found on many plant species, it is often difficult to distinguish between real hosts (i.e. plants allowing feeding and completion of an entire life cycle) and suspected hosts (insects incidentally found on a plant). The presence of *B. tabaci* on a particular plant species thus is not proof of host suitability. Especially in seasons and locations with high population densities, *B. tabaci* can be found on many plants. Feeding behaviour or oviposition as host indicators are also ambiguous characters because whiteflies can explore a plant several times before rejecting it or laying eggs. Furthermore, eggs laid on some plants could have critically delayed development or not develop at all. For the purpose of risk assessment, the more suitable a plant is as a host (feeding and successful nymphal development), the higher the risk it presents as a commodity.

The recent literature (Bayhan et al., 2006b; Evans, 2007; DAF-GWA, 2008; Simmons et al., 2008; Abd-Rabou and Simmons, 2010; Li et al., 2011a) distinguishes three categories: (i) host plant status (full life cycle supported) confirmed under experimental conditions (49 species—11 families); (ii) host plant status confirmed from field observations (509 entries—102 families); (iii) unconfirmed data (610 entries—104 families).

Because of its broad host plant range, suitable hosts for *B. tabaci* are found in almost every environment, in agricultural and horticultural crops and in wild plants.

3.1.5. Risk assessment area

The RA area is the territory of the European Community (EU 27) excluding the overseas territories.

3.1.6. Occurrence of *B. tabaci*

3.1.6.1. Origin and global occurrence

B. tabaci is reported from all continents, except Antarctica (Figure 3) and is considered to be one of the most invasive species worldwide (Global Invasive Species Database, online). Several geographic origins have been proposed for *B. tabaci*: Asia, India, Africa, and North and South America (De Barro et al., 2011). However, recent evolutionary reconstruction based on mtCO1 data provided evidence that sub-Saharan Africa is the most likely geographical origin of *B. tabaci* (De Barro et al., 2011, De Barro, 2012).

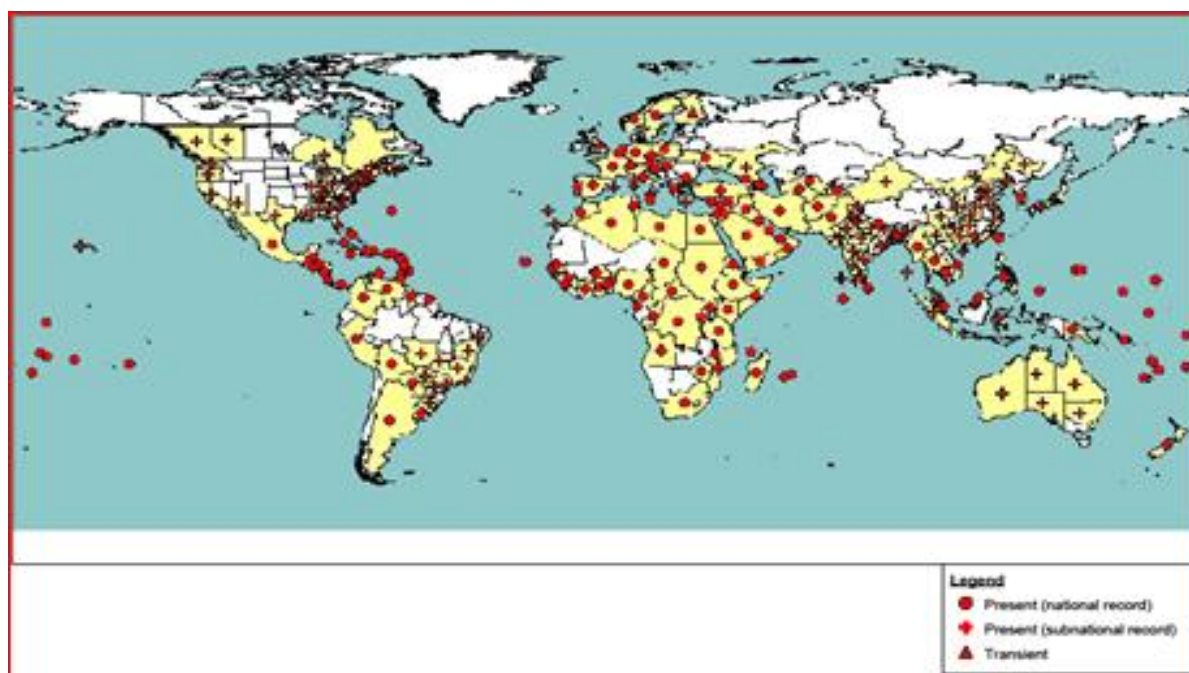


Figure 3: World distribution of *B. tabaci* (EPPO PQR, 2012b)

The *B. tabaci* genetic groups described in Table 1 are generally affiliated with continents, with, for example, New World species present in the Americas, or a few countries such as Uganda or Italy. *B. tabaci* outside their endemic areas are often associated with particular host plant species and this suggests an introduction event (e.g. SSA2 in Spain or in France). In contrast to all other species, MEAM1 and Med have been introduced to almost everywhere in the world and, once established, rapidly became the predominant species. *B. tabaci* MEAM1 and Med occur globally, and while this is

not proven for other species, both MEAM1 and Med are highly invasive as their area of distribution is nearly the distribution area of the whole *B. tabaci* species complex.

3.1.6.2. Occurrence in the risk assessment area

Four species of *B. tabaci* are present in the RA area (De la Rúa et al., 2006; Arnó et al., 2009). MEAM1 and Med are widespread and also present outdoors along the coastal Mediterranean regions of Europe (Figure 4). In addition, two distinct *B. tabaci* species are described: the Italy species (previously biotype T) and the sub-Saharan Africa 2 species (SSA2, previously biotype S). In Europe, these species have limited geographical distribution. The Italy species has been reported only on *Euphorbia characias* in southern Italy and Sicily (Simón et al., 2003; Demichelis et al., 2005), and SSA2 which was first reported on *Ipomea indica* in Spain (Banks et al., 1998 in De la Rúa et al., 2006) has recently been found on soybean in France (Gauthier, 2010).

Twenty-six *B. tabaci* species, most of them being endemic in countries around the world, are so far not reported in Europe. The terms “European populations” and “non-European populations” of *B. tabaci* used in the Council Directive 2000/29/EC do not refer to specific populations or taxonomic entities but stipulate a geographic origin of *B. tabaci*, from in- and outside the EU.

B. tabaci has been reported from most of the 27 countries in the RA area, and in those cases for which a species identification was conducted MEAM1 and Med were almost exclusively found. In countries where *B. tabaci* is established, density and spatial distribution depend on prevailing climatic conditions. In northern Europe, *B. tabaci* occurrence is in protected crop production systems only while in southern Europe it is present in greenhouses and in open fields. Except in the Mediterranean coastal region (Cyprus, Greece, Malta, Italy, south of France, certain parts of Spain and Portugal), *B. tabaci* occurrence is restricted to greenhouses. In the EU-27, *B. tabaci* is endemic in areas between 28° 3' (Spain) and 44° 8' N (northern Italy) latitudes and, when the Canary Islands are excluded (longitude 16° 19' W), between 9° 19' W (Portugal) and 33° 58' E (Cyprus) longitudes (Figure 4; Appendix B).

Both *B. tabaci* species MEAM1 and Med are rarely sympatric. In some European countries, Med predominates and MEAM1 is almost absent, as in Spain (Simón et al., 2007; BemisiaRisk, 2010), Greece (Tsagkarakou et al., 2007, 2012) and in France where MEAM1 has been found only in a botanical garden in Nice (Dalmon et al., 2008; Gauthier, 2010). In contrast, MEAM1 was the only species present in Cyprus (Vassiliou et al., 2008) while in Italy, both Med and MEAM1 were found in warmer regions including the southern parts (Sardinia and Sicily) and the north-western coast (Liguria) (Parrella et al., 2012).

In several European countries (Denmark, Estonia, Latvia, Lithuania, Romania, Slovakia, Slovenia, Finland, Ireland, Sweden, United Kingdom) and in central and northern parts of Portugal, *B. tabaci* is reported as absent (for detailed information, see Appendix C). Sweden, Ireland, United Kingdom, Finland and parts of Portugal, Madeira and the Azores archipelagos are officially “free” of *B. tabaci* and have a declared status of protected zone (PZ; Annex IB of Council Directive 2009/29/EC). However, *B. tabaci* is frequently intercepted in these PZs (Cuthbertson et al., 2011; EPPO, 2012a) and is subject to eradication.

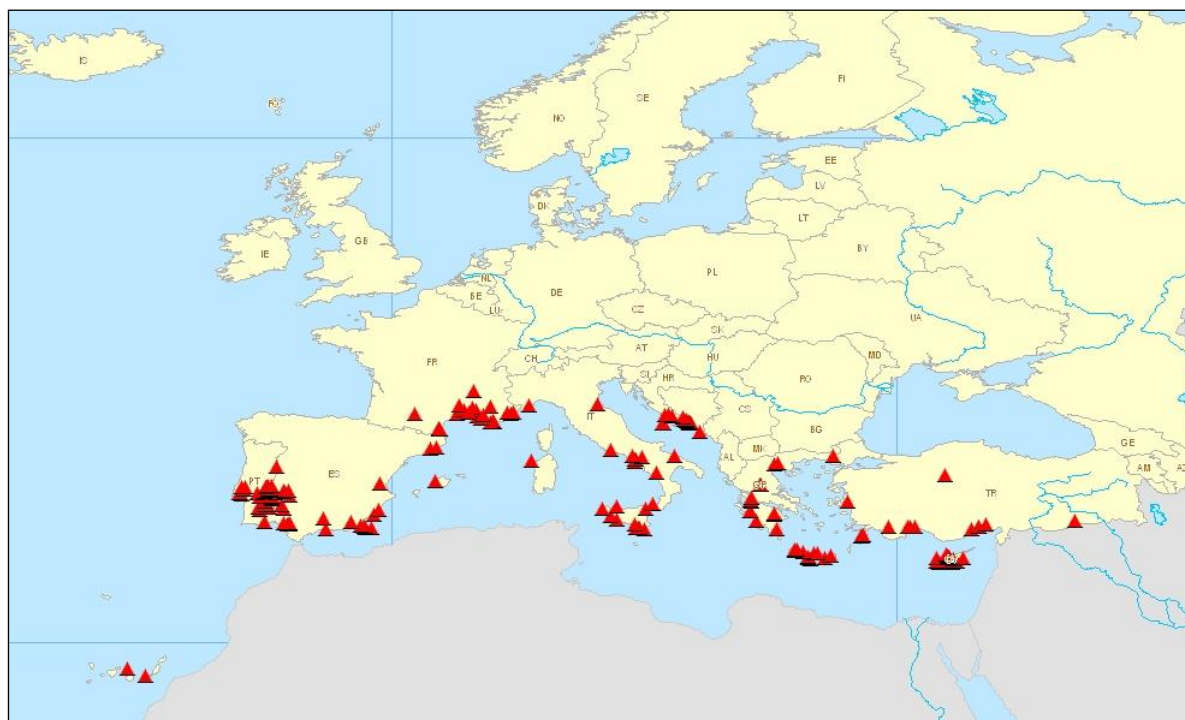


Figure 4: Distribution map of *B. tabaci* in open fields in the RA area including information from Bosnia and Herzegovina, Croatia and Turkey (for GPS data and references see Annex C, table C.2)

3.1.6.3. Uncertainties about the occurrence of *B. tabaci* in the risk assessment area

Because early reports of *B. tabaci* interceptions did not include species identification, there is uncertainty over the exact identity of *B. tabaci* species. Because of this lack of precision, it is not possible to determine whether intercepted species indeed were alien to Europe or were already present. In addition, the situation in terms of presence/absence of *B. tabaci* and also of the precise species identity might have changed (see Appendix C) since the surveys and reports were done.

The exact geographic borders of *B. tabaci* distribution cannot be clearly defined. Although for northern European countries, including those with PZ status, outdoor populations of *B. tabaci* are not expected in some European countries, a few generations of *B. tabaci* might occur outdoors when conditions are favourable in summer and early autumn for insect populations to develop.

3.1.7. Plant viruses transmitted by *B. tabaci*

Virus species transmitted by *B. tabaci* belong to the genera *Begomovirus*, *Crinivirus*, *Ipomovirus*, *Carlavirus* and *Torradovirus*. All viruses are transmitted by *B. tabaci*, although significant differences in the mode of virus transmission exist. This is decisive for epidemiology.

3.1.7.1. Transmission modes and virus acquisition

The circulative, persistently transmitted plant viruses need to pass through the vector prior to reinfection for virus transmission. After acquisition of the virus with phloem sap, a latency period of several hours follows after which virus transmission takes place (Ghanim et al., 2001). Once acquired, virus is retained in the vector often for its entire lifespan, during which the insect remains viruliferous to transmit the virus.

The non-circulative viruses do not pass through the insect and, consequently, *B. tabaci* remains viruliferous only by continuous uptake of the virus with plant sap. Viruses are retained in the vector for seconds to hours (non-persistent) and hours to days (semi-persistent) (Hogenhout et al., 2008) and

thus virus transmission is almost immediate. Non-persistently transmitted viruses are retained by the vector mainly in the stylet (food canal) (Ammar et al., 1994), whereas semi-persistent viruses are retained mainly in the foregut (Gray and Banerjee, 1999). Different rates of acquisition and transmission exist for NVs (see Jeyanandarajah and Brunt, 1993; Mansour and Al-Musa, 1993; Amari et al., 2008). Notwithstanding this, *B. tabaci* whiteflies retain non-circulative viruses for only a short time and transmission is lost 24 hours after removal from infected plants (Webb et al., 2012).

3.1.7.2. The viruses transmitted by *B. tabaci*

The genus *Begomovirus* (family *Geminiviridae*) comprises viruses with either monopartite or bipartite single-stranded DNA genomes. New virus species are constantly described (Zambrano et al., 2012) and this rapidly expanding genus contains to date more than 200 acknowledged species and approximately 100 more for which their taxonomic status as species has not yet been approved (Brown et al., 2012). In addition to new species, an enormous genetic variation exists within the virus species and a large number of strains and unique genome variants are described and associated with particular disease phenotypes (Kon and Gilbertson, 2012).

A large molecular diversity between begomoviruses exists. Recombination events in begomoviruses are very frequent and this generates novel begomoviruses and plays a major role in the emergence of new disease phenotypes (Melgarejo et al., 2011; Kon and Gilbertson, 2012). *B. tabaci* acts as an efficient mediator because recombination requires mixed infections and those are introduced with polyphagous whiteflies feeding on many plant species. This expands the host range of begomoviruses (Bedford et al., 1994) but, furthermore, it brings together into one host otherwise disconnected plant viruses (Tiendrebeogo et al., 2012).

In addition, monopartite begomoviruses are often associated with small DNA molecules called satellite DNA of which alphasatellites and betasatellites are known. The betasatellites (DNA beta) are most significant for begomovirus diseases and interfere with host resistance responses and/or increase virus virulence. In some cases systemic symptoms are expressed only when DNA beta is present (Saunders et al., 2000; Mansoor et al., 2003; Saeed et al., 2005). Thus, DNA beta satellites are pathogenicity determinants and, when present, disease phenotypes are generally more severe. For some viruses these molecules are essential for the induction of typical disease symptoms in the field. DNA beta molecules depend on the helper virus for replication and encapsidation; however, their association with a particular virus is not very tight. Thus they can be replicated and encapsidated by several begomoviruses.

Begomoviruses are transmitted by *B. tabaci* in a persistent circulative manner (Czosnek et al., 2002; Hogenhout et al., 2008) and there are intrinsic interactions between whiteflies and viruses that determine the efficiency of transmission (Bedford et al., 1994; Markham et al., 1994). Nevertheless, it can be assumed that all *B. tabaci* transmit begomoviruses albeit with various levels of efficiency (McGrath and Harrison, 1995). For TYLCV, a single insect is capable of acquiring and transmitting the virus to infect tomato plants. Even nymphs can ingest and transmit begomoviruses, but it is the adult whiteflies that spread the disease. Once acquired, begomoviruses are retained in the insects for a period of several weeks up to the entire lifespan, although in most cases virus is detected for much longer than infectivity is retained. For circulative viruses, this means that, even in the temporary absence of virus host plants, virus spread with virulent whiteflies takes place once a susceptible virus host is found. Transovarial transmission of TYLCV to the offspring was reported in one case (Ghanim et al. 1998); however, this was not confirmed in independent studies with additional *B. tabaci* populations and begomovirus species (Bosco et al., 2004). Thus, from all evidence reported so far, it cannot be concluded that infectious begomoviruses are transovarially passed onto the insect progeny.

All viruses that are non-circulatively transmitted by *B. tabaci* have single-stranded RNA genomes.

The genus *Crinivirus* (family *Closteroviridae*) is composed of 12 accepted species recognised by the International Committee on Taxonomy of Viruses (ICTV) and two proposed species (Navas-Castillo

et al., 2011), of which six are transmitted by *B. tabaci*: *Bean yellow disorder virus* (BnYDV) (Martín et al., 2011), *Cucurbit yellow stunting disorder virus* (CYSDV) (Celix et al., 1996), *Lettuce chlorosis virus* (LCV) (Duffus et al., 1996), *Lettuce infectious yellows virus* (LIYV) (Duffus et al., 1986), *Sweet potato chlorotic stunt virus* (SPCSV) (Sim et al., 2000), *Tomato chlorosis virus* (ToCV) (Wintermantel and Wisler, 2006) and *Cucurbit chlorotic yellows virus* (CCYV) (Okuda et al., 2010). Criniviruses are typically limited to the phloem of plants and are transmitted in a semi-persistent manner by *B. tabaci* (Wisler et al., 1998).

The genus *Ipomovirus* (family *Potyviridae*) contains five member species, that are semi-persistently transmitted by *B. tabaci*: *Cassava brown streak virus* (CBSV) (Maruthi et al., 2005), *Cucumber vein yellowing virus* (CVYV) (Cohen and Nitzany, 1960), *Squash vein yellowing virus* (SqVYV) (Adkins et al., 2008), and *Sweet potato mild mottle virus* (SPMMV). The transmission of ipomoviruses is characterised as semi-persistent.

The genus *Carlavirus* (family *Flexiviridae*) groups 43 species that are transmitted by aphids, except for two, which are *B. tabaci* transmitted: *Cowpea mild mottle virus* (CPMMV) (Iwaki et al., 1982) and *Melon yellowing-associated virus* (MYaV) (Nagata et al., 2003). CPMMV is non-persistently transmitted by *B. tabaci* to beans and tomato among other species (Jeyanandarajah and Brunt, 1993). Symptoms vary on different hosts and in different seasons.

The recently emerging genus *Torradovirus* (family *Secoviridae*) has two recognised members, the type species *Tomato torrado virus* (ToTV) (Verbeek et al., 2007) and *Tomato marchitez virus* (ToMarV) (Verbeek et al., 2008). Both viruses have only recently been discovered to cause disease in tomato. Whitefly transmission has so far been experimentally confirmed only for ToTV.

3.1.7.3. Host range and symptoms

Agricultural production in tropical and subtropical regions is particularly threatened by *B. tabaci*-transmitted viruses causing significant diseases in beans, cotton, cucurbits, pepper, cassava and tomatoes. The plant species and families that are host to *B. tabaci*-transmitted viruses are summarised in Appendix B). It shows that each of the important crop species is host to one or more *B. tabaci*-transmitted viruses. The main host plants threatened by *B. tabaci*-transmitted viruses in Europe are tomato and cucurbit crops, while wild plants including weeds can serve as reservoirs for the respective crop viruses (Papayiannis et al., 2011). This risk assessment document thus concentrates on *B. tabaci*-transmitted viruses threatening tomato and cucurbit crops in the EU and considers relevant alternative hosts and virus reservoirs.

Begomoviruses infect a wide range of dicotyledonous plants, with the range of natural hosts of individual viruses limited however to few species. The main target hosts are Euphorbiaceae, Malvaceae, Cucurbitaceae and Solanaceae. Symptoms of begomovirus infections in plants consist of leaf curling or vein yellowing or yellow mosaic. Green to bright yellow mosaic symptoms and leaf deformation and chlorosis are often signs of severe disease. Early infections result in severe growth reduction, stunting and deterioration of the entire plant. Depending on the onset of virus inoculation by whiteflies, flowering is reduced and fruit development is aborted, and thus early infections can lead to the entire loss of the crop while infections at later stages of development are often mild and losses are tolerable.

Tomato is the principal host and key target for more than 60 distinct begomovirus species and even more strains (Appendix B). This is because tomato cultivation is done in almost any locality in the world. The distinct begomoviruses are transmitted by whiteflies from existing reservoir hosts or by human introduction and evolve and adapt to the new host tomato via recombination and genetic reassortment (Salati et al., 2002; Rojas et al., 2005a,b; Rojas and Gilbertson, 2008; Chen et al., 2009). The simultaneous evolution of new and diverse begomovirus species at multiple locations results in highly similar disease phenotypes (Melgarejo et al., 2011; Kon and Gilbertson, 2012). This is reported for bean (Garrido-Ramirez et al., 2000; Gilbertson et al., 1993a, b) cassava (Sserubombwe et al., 2008)

and cotton (Sanz et al., 2000; Tahir et al., 2011) but best demonstrated by the multitude of tomato (yellow) leaf curl disease reports from all over the world (Appendix B).

TYLCV is a complex of begomovirus species that cause tomato yellow leaf curl disease, which is a serious threat to tomato production in many tropical and subtropical regions worldwide, having a severe impact on crop production and yield (Czosnek and Laterrot, 1997). Symptoms of the disease consist of a more or less prominent upward curling of leaflet margins, reduction in leaflet area and yellowing of young leaves, together with stunting and flower abortion. Infection results in a general decrease in plant growth and reduced yields, and production is almost entirely lost if plants are infected during early growth. The first reports of damage caused by this disease were from Israel in the late 1930s and tomato plantings in Middle Eastern countries have been severely affected since the 1960s (Cohen and Antignus, 1994; Czosnek and Laterrot, 1997).

Criniviruses infect species of the three mayor crop families: the Solanaceae (tomato, potato, pepper), Cucurbitaceae (melon, watermelon, squash and cucumber) and Leguminosae (bean) (Barbosa et al., 2011; Martín et al., 2011; Navas-Castillo et al., 2011; Freitas et al., 2012). All criniviruses induce similar symptoms in their corresponding hosts that are often mistaken for nutritional deficiencies: these symptoms consist of interveinal yellowing of leaves from the middle to the lower parts of plants as the primary symptom; the interveinal areas eventually become completely yellow while the veins remain green. Symptom-bearing leaves remain turgid, or become brittle, as in the case of cucumber (CYSDV) and tomato (ToCV). These symptoms appear as early as two to three weeks post inoculation, depending on environmental conditions. Symptoms develop sooner and more intensely on plants grown under long days and high light intensities. *B. tabaci*-transmitted criniviruses in cucurbits produce yellowing symptoms on leaves with serious leaf distortion, stunted growth and crippling of the entire plant following severe infection. Plants inoculated at early stages produce only few flowers and fruit development generally is reduced or absent.

Ipomoviruses are pathogens of the four mayor cucurbit species, melon, watermelon, squash and cucumber (SqVYV, CVYV). They also cause diseases in sweet potato (SPCSV) and cassava (CBSV, UCBSV). SqVYV symptoms in melon and cucumber are mild or transient (Adkins et al., 2007) while in watermelon infections of SqVYV result in vein yellowing in squash and watermelon, and vine decline, collapse and plant death in the case of watermelon (Adkins et al., 2007). CVYV-infected plants respond with a pronounced vein yellowing and vein clearing on leaves and stunting of the entire plant (Cohen and Nitzany 1960; Yilmaz et al., 1989) and sudden plant death as a result of early infections (Cuadrado et al., 2001). Symptoms produced are most obvious in the apical part of infected plants and on fruits. Besides fruit discoloration, deformations and blisters, splitting of fruits has also been observed (Janssen and Cuadrado, 2001; Louro et al., 2004). Courgette also can be infected, with very mild or absent symptoms, while some cultivars respond with chlorotic mottle and vein yellowing symptoms on leaves.

Torradoviruses such as ToTV cause symptoms in tomato plants expressed as necrotic lesions at the base of the leaflets, longitudinal necrotic lesions on the stems, and necrotic line patterns or blotches followed by deformations on fruits (Amari et al., 2008; Batuman et al., 2010; Hanssen et al., 2010; Verbeek et al., 2008, 2010). The virus naturally infects tomato (*S. lycopersicum*), and several wild plant species belonging to various plant families, but experimental hosts include aubergine (*Solanum melongena*) and pepper (*Capsicum annum*) (Amari et al., 2008).

Carlavirus CPMMV causes mottling and inconspicuous banding of minor veins on tomato (Brunt and Phillips, 1981). MYaV produces symptoms of yellowing and mottling on older leaves in melon (Nagata et al., 2003).

3.1.7.4. Detection and identification of *B. tabaci*-transmitted viruses

Begomovirus species identification is by molecular methods only, with sequences of the entire genome of monopartite viruses or the complete DNA-A genome component sequence of bipartite

viruses used for species demarcation. Nucleotide sequence identity of < 89 % indicates distinct species (Brown et al., 2012), with the taxonomic status of recombinant viruses then depending on the relatedness to the parental viruses and the degree of recombination. Species identification also considers, among other things, natural host range and symptom phenotype, although these criteria are mostly considered to define begomovirus strains (Brown et al., 2011). For detection and differentiation of begomoviruses in infected plants, molecular tools based on polymerase chain reaction (PCR) are available and generally used (Lefevre et al., 2007a; Tiendrebeogo et al., 2010).

For all whitefly-transmitted viruses diagnostics are based on PCR, reverse transcription (RT)-PCR and/or enzyme-linked immunosorbent assay (ELISA). Methods for reliable detection, identification and discrimination of virus species and strains are generally available (Gil-Salas et al., 2007; Verbeek et al., 2007; Adkins et al., 2009; Tavasoli et al., 2009; Wintermantel, 2010; Wintermantel and Hladky, 2010).

3.1.7.5. Global occurrence of *B. tabaci*-transmitted viruses

Intensive globalisation and modern agricultural practices have contributed to a worldwide dissemination of viruses transmitted by *B. tabaci* (Figures 5–8). In particular, the emergence of begomoviruses is linked to the appearance of *B. tabaci* as a major pest of crops worldwide (Brown et al., 1995a, b). Outbreaks of begomovirus diseases are often associated with incursions of new strains or even new species of virus (Brown, 2000; Andrade et al., 2006; Delatte et al., 2006; Lefevre et al., 2007b), with *B. tabaci* MEAM1 and Med most commonly associated with virus epidemics.

The introduction of TYLCV, the most damaging DNA virus for tomato and cucurbit crops, into the Dominican Republic in 1990, probably with tomato transplants, resulted in virus spread throughout the Caribbean islands and was a landmark in terms of a successful invasion of TYLCV into the Americas. TYLCV was then found in Florida, emerged in Mexico, was identified in Texas and Arizona and only a little later in California. In a very short time, TYLCV, which was first described in the Middle East, has become a major threat to tomato production in the world, including China (Mughra et al., 2008). Its rapid spread is most likely a result of movement of infected plants, movement of plants harbouring viruliferous whiteflies and/or movement of *B. tabaci* MEAM1 and Med as efficient virus vectors.

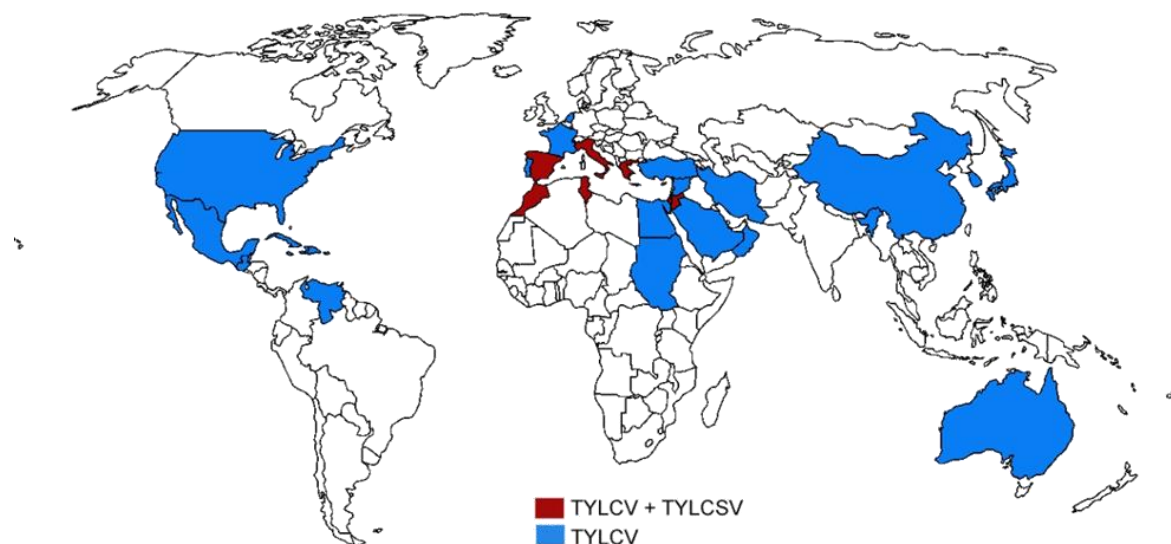


Figure 5: World distribution of TYLCV and TYLCSV ((*Tomato yellow leaf curl Sardinia virus*) infecting tomato (data and references in Appendix B)



Figure 6: World distribution of begomoviruses other than TYLCV and TYLCSV, infecting tomato (data and references in Appendix B)



Figure 7: World distribution of begomoviruses infecting Cucurbitaceae (data and references in Appendix B)

Viruses other than begomoviruses that are transmitted by *B. tabaci* belong to diverse genera of viruses with RNA genomes. Criniviruses such as CYSDV and ToCV are considered “emerging viruses” and are increasingly recorded from a number of European, American and Asiatic countries. Ipomoviruses are present in Europe, North America, Africa and the Middle East. On the other hand, *B. tabaci*-transmitted carlaviruses (such as CPMMV and MYaV) are present in Africa, Asia, South America, the Middle East and Oceania. Torradoviruses—ToTV and ToMarV—are found in Europe, Oceania and in Central America (see Figure 8; detailed data and references in Appendix B).

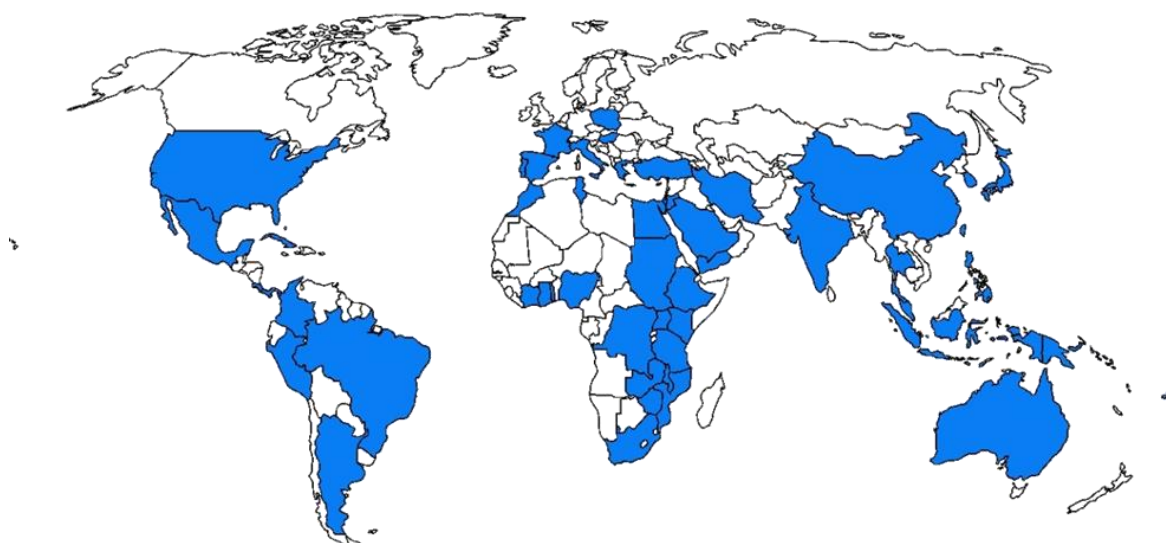


Figure 8: World distribution of *B. tabaci*-transmitted RNA viruses infecting crops (data and references in Appendix B)

3.1.7.6. Occurrence of *B. tabaci*-transmitted viruses in the risk assessment area

At present four begomoviruses, four criniviruses, one ipomovirus and one torradovirus have been reported in Europe. An overview of the *B. tabaci*-transmitted viruses present in Europe is shown in Table 2.

Table 2: *Bemisia tabaci*-transmitted viruses in Europe

Genus, species	Reference	Countries
<i>Begomovirus</i>		
<i>Tomato yellow leaf curl virus</i>	Moriones et al., 1993; Accotto et al., 2000	Cyprus, France, Greece, Italy, Portugal, Spain, Malta*
<i>Tomato yellow leaf curl Sardinia virus</i>	Kheyr-Pour et al., 1991; Crescenzi et al., 2004; Nannini et al., 2009	Greece, Italy, Spain
<i>Tomato yellow leaf curl Malaga virus</i>	Monci et al., 2002	Spain
<i>Tomato yellow leaf curl Axarqia virus</i>	García-Andrés et al., 2006	Spain
<i>Crinivirus</i>		
<i>Cucurbit yellow stunting disorder virus</i>	Célix et al., 1996	France, Portugal, Spain, Greece
<i>Tomato chlorosis virus</i>	Acotto et al., 2001	Spain, Portugal, Italy, Greece, France, Cyprus, Hungary*
<i>Sweet potato chlorotic stunt virus</i>	Valverde et al., 2004	Spain
<i>Bean yellow disorder virus</i>	Segundo et al., 2004	Spain
<i>Ipomovirus</i>		
<i>Cucumber vein yellowing virus</i>	Cuadrado et al., 2001	Spain, Portugal, France, Cyprus
<i>Torradovirus</i>		
<i>Tomato torrado virus</i>	Verbeek et al., 2007	Spain, Hungary, Poland, Italy, France

*response to EFSA questionnaire sent to NPPO

From the large number of begomoviruses associated with Tomato yellow leaf curl disease (TYLCD), four species are present within the RA area. TYLCD was first reported in the Jordan Valley (now Israel) in the late 1930s but only in 1961 was TYLCV identified as the causal agent of this disease. During the 1970s, TYLCV was found throughout the Middle East and then spread to many countries in the world including European countries. It was found in Cyprus in 1982, Portugal in 1995, Spain in 1997, France in 1999 and Greece in 2000 (Navas-Castillo et al., 2011). TYLCD was reported from Italy in 1989 and the begomovirus causing this disease was found to be sufficiently different from TYLCV to justify *Tomato yellow leaf curl Sardinia virus* (TYLCSV) as a new species. TYLCV was subsequently also found in Italy in 2002. Both viruses are now present in Italy, Greece and Spain. In Spain, in addition to TYLCV, recombinant viruses *Tomato yellow leaf curl Malaga virus* (TYLCMaV) (Monci et al., 2002) and *Tomato yellow leaf curl Axarquia virus* (TYLCAxV) (García-Andrés et al., 2006) occur which are naturally occurring recombinants resulting from a genetic exchange between TYLCV and TYLCSV-Es (García-Andrés et al., 2006) and indicating the dynamics of virus populations involved in these diseases.

From the early 1990s onwards criniviruses began their appearance in Europe. CYSDV was found in *Cucurbitaceae* crops from Spain during the early 1990s, and subsequently in Portugal in 1998, Greece in 2000 and France in 2001. Tomato crops infected with ToCV have been found in Spain and Greece since 1997, Portugal in 1998, Italy in 2000, France in 2002 and Cyprus in 2004. ToCV was found in Hungary in 2007 (response to EFSA questionnaire sent to the NPPO). In Spain two minor crop species, green beans and sweet potato, were found infected with BnYDV and SPCSV, respectively.

The ipomovirus CVYV was first observed in cucumber in the late 1950s in the Jordan valley area of Israel (Cohen and Nitzany, 1960) and is now found also on melon and watermelon crops in Spain, Cyprus, Portugal and France (Papayiannis et al., 2005; Navas-Castillo et al., 2011).

Only very recently a newly emerging virus, the ToTV was described and first detected in Spain in 2001, subsequently identified in Poland in 2003 and then reported from Hungary in 2007, France in 2008 and Italy in 2009 (Navas-Castillo et al. 2011).

Emerging virus diseases

Over the last two decades, previously unknown viruses emerged in Europe leading to serious diseases in agriculture and horticultural crops. The appearance of new viruses is a result of global trade and the international exchange of germplasm and consequently viruses previously confined to a specific geography can almost simultaneously appear across the world. The establishment and spread of these viruses is tightly associated with *B. tabaci*.

In the mid-1990s symptoms of yellowing and necrosis at the base of leaflets were described on tomato in the Canary Islands and later similar symptoms were found on tomato in Murcia, Spain. The causative agent was described as ToTV (Verbeek et al., 2007). Soon after, the virus was confirmed in the Canary Islands, it was identified in Poland (2003), Australia (2005), Hungary (2007), France, Panama and Colombia (2008) and Italy (2009) (Navas-Castillo et al., 2011; Verbeek and Dullemans, 2012). Also, during the first decade of this century, torrado-like symptoms in tomato have been found in the state of Sinaloa, Mexico. Here, symptoms were characterised as wilting, and include leaf, stem, and fruit necrosis. A new virus species, related to ToTV, was discovered, characterised and provisionally named *Tomato marchitez virus* (ToMarV) (Verbeek et al., 2008). All viruses have emerged within a short period of time, with spread associated with whiteflies as efficient vectors. Because these viruses are non-circulatively transmitted by *B. tabaci* and have only short association with their vectors (semi-persistent transmission), dissemination of virus over long distances is only possible with infected plant materials.

The introduction of viruses into new geographic regions or crops is not sufficient prerequisite for their widespread dissemination. *B. tabaci* remain viruliferous for their entire lifespan once begomoviruses are ingested, and thus adult whiteflies can transmit virus for long periods. Criniviruses, ipomoviruses

and carlaviruses are transmitted in a non-circulative mode and therefore transmission by *B. tabaci* adults is short and lost within few days at most (Martín et al., 2011; Webb et al., 2012). Agricultural situations in which host plants and *B. tabaci* populations are abundant favour the establishment and spread of criniviruses such as ToCV in solanaceous crops (Fortes et al., 2012) and CYSDV in cucurbitaceous crops (Berdiales et al., 1999). Other criniviruses, such as BnYDV, with a host range restricted to few Leguminosae can disappear following an initial outbreak that has, however, caused serious damage and economic losses (Segundo et al., 2004; Janssen et al., 2011).

Changes in the vector population can have serious implications for virus infections too. The crinivirus LIYV emerged during the 1980s in California when the New World species of *B. tabaci* (formerly known as biotype A) was endemic in the United States. This disease caused very serious losses in melon and lettuce. The introduction of the species formerly known as *B. tabaci* biotype B (MEAM1 species) then led to the displacement of the New World species (formerly known as biotype A) and, because MEAM1 transmits LIYV only very inefficiently, the incidence of LIYV in California reduced significantly (Rojas and Gilbertson, 2008) and the virus now has almost disappeared.

3.1.7.7. Uncertainties about the occurrence of viruses transmitted by *B. tabaci* in the risk assessment area

As far as virus diseases of crop plants are concerned, viruses and virus diseases of major European crops are generally well characterised and understood. Crops in Europe are thoroughly monitored and new viruses or unusual diseases are quickly recognised, which is especially true of crops of intensive agriculture and high economic significance (tomato, cucurbits). Uncertainty however exists on the presence and fate of whitefly-transmitted viruses in the environment. Wild plants may play a crucial role as virus sources in the onset of a new infection cycle, especially for the non-circulative transmitted RNA viruses for which overwintering hosts have not yet been identified. An increasing number of recently emerging virus diseases can be associated with hosts including wild plant species (e.g. for CYSDV (Wintermantel et al., 2009), CVYV (Morris et al., 2006; Janssen et al., 2002), or ToCV (Morris et al., 2006), and the range of alternative hosts for overwintering and as sources of virus infections can be considered much larger than previously recorded.

3.1.8. Pest status

3.1.8.1. Global situation

The current global status of *B. tabaci* as a pest refers mainly to MEAM1 and Med, both of which are highly invasive, worldwide distributed, highly polyphagous (over 1 000 host plants reported; see a comprehensive list in Appendix B), resistant to a large number of insecticides (Dennehy et al., 2010; Li et al., 2011b), and particularly damaging by transmitting viruses causing serious crop diseases (De Barro et al., 2011; Navas-Castillo et al., 2011). Notwithstanding the major significance of MEAM1 and Med, other *B. tabaci* species can also be important agricultural pests by efficiently transmitting virus diseases in major world food and fibre crops, such as cassava in Africa and India (Legg et al., 2002; Legg and Fauquet, 2004) and cotton in India and Pakistan (Sanz et al., 2000).

The global status of *B. tabaci* as a pest has evolved through time. Until 1980, *B. tabaci* was a minor pest of cotton and other crops of tropical and subtropical regions and under control by insecticide applications. In the late 1980s, the introduction and subsequent global invasion of MEAM1 has resulted in the displacement of relatively innocuous, indigenous populations of other *B. tabaci* species (Brown, 2007), and *B. tabaci* has reached the status of global pest with serious economic impact (De Barro et al., 2011). As result MEAM1 is now considered as one of the 100 worst invasive alien species in the world (Global Invasive Species Database, online).

The worldwide expansion of MEAM1 was recently followed by the invasion of Med, most probably via the trade of ornamentals (De Barro et al., 2011). Med quickly spread from its presumed area of origin, the Mediterranean basin, to other parts of the world (Chu et al. 2006; Ueda and Brown 2006;

De Barro et al. 2011; Hu et al., 2011; McKenzie et al., 2012). It became the predominant—or even the only—*B. tabaci* species present, and has sometimes displaced the MEAM1 species, particularly where insecticides are frequently applied (Horowitz et al., 2005; Tahiri et al., 2006; Simón et al., 2007; Tsagkarakou et al., 2007; Dalmon et al., 2008; De Barro et al., 2011; Hu et al., 2011). The higher insecticide resistance of Med compared with MEAM1 is regarded as the key factor in its current prevalence (Horowitz et al., 2005; Crowder et al., 2010a, b; Dennehy et al., 2010; Luo et al., 2010; Li et al., 2011b; Rao et al., 2011). However, differences between MEAM1 and Med (Tables 3 and 4) mostly related to host plants (species and cultivars), life history traits and mating behaviour, tend to promote MEAM1, in particular in cases where few or no pesticides are used. As a result, depending on the environmental conditions and agricultural systems, either MEAM1 or Med might be the predominant species (see Tables 3 and 4 for references).

Table 3: Life-history traits and genetic differences between *B. tabaci* MEAM1 and Med to emphasise the pest potential of the species

	MEAM 1	Med	References
GENETIC DIVERSITY	+	++	Tsagkarakou et al., 2007, 2012; Dalmon et al., 2008; BemisiaRisk, 2010; Gueguen et al., 2010; De Barro and Ahmed, 2011; Saleh et al., 2012
HOST PLANTS	>500 hosts	>500 hosts	Chu et al., 2006; De Barro et al., 2011; Rao et al., 2011
Vegetables	++	+	
Ornamentals and weeds	+	++	
INSECTICIDE RESISTANCE	+	++	Horowitz et al., 2005; Crowder et al., 2010b; Dennehy et al., 2010; Luo et al., 2010; Li et al., 2011b
ACQUISITION AND TRANSMISSION OF VIRUSES	+	+	De Barro et al., 2011

++ indicates superiority over +

B. tabaci is a vector of a large number of plant viruses in the genera *Begomovirus*, *Crinivirus*, *Carlavirus*, *Ipomovirus* and *Torradovirus* (Appendix B). The extent to which these viruses have pest status is directly related to that of its vector. A large number of begomovirus species are found in South America and in the Caribbean region, many of which infect wild plant species, e.g. from the family Malvaceae. With the introduction of the polyphagous MEAM1 into these areas, these viruses were transmitted from the wild to tomatoes and from there back to wild plants. Although unassuming before, in the mid-1990s these begomovirus species became the major limiting factor to tomato production in many areas of Brazil, causing yield losses up to 100 % (Faria et al., 1997; Ribeiro et al., 1998). In Africa and in India begomoviruses cause serious disease in cassava, the cassava mosaic disease (CMD). Similar to TYLCD, CMD symptoms are very similar, but the disease is caused by distinct begomovirus species and their strains. Seven species occur in Africa (Legg et al., 2006; Legg, 2010) and two distinct virus species cause CMD in India and Sri Lanka (Saunders et al., 2002). Recombinant viruses are frequently found in CMD-affected plants in Africa and some infections of those recombinant viruses are associated with more severe disease symptoms. While considerable diversity of the cassava viruses exist, the recombinant East African cassava mosaic virus strain Uganda, has reached epidemiological significance and is the predominant virus infecting cassava in east and central Africa (Legg et al., 2006).

Diseases caused by the crinivirus CYSDV can result in major yield reductions, and high economic losses are reported. An outbreak of CYSDV in 2006 in California and Arizona, United States, and Sonora, Mexico, resulted in almost 100 % virus infection in melon crops in the region (Brown et al., 2007; Kuo et al., 2007). Other criniviruses such as LIYV caused damage in the 1980s in melon, lettuce and sugarbeet in south-west America (Wisler et al., 1998). ToCV is present in at least 20 countries worldwide (see Appendix B) and, as with CYSDV, an estimate of the economic importance of ToCV is pending exact data, but it causes yield reductions from loss of photosynthetic area, reduced fruit growth and delayed ripening.

On the other hand, carlaviruses such as CPMMV are generally not considered to be of great economic importance (Reddy and Rajeshwari, 1984; Demski and Kuhn, 1989).

Ipomoviruses causing serious diseases in food crops occur in many parts of the world, e.g. CBSV in Africa, SqVYV in North America, and CVYV in the Mediterranean basin, Africa and the Middle East. Cassava brown streak disease (CBSD) is a disease caused by two *B. tabaci*-transmitted viruses, CBSV and *Ugandan Cassava brown streak Uganda virus* (UCBSV) (Winter et al., 2010) and leads to the decay of the tuberous root rendering it inedible. The disease can reach incidences of up to 100 % (Hillocks et al., 2001) and has a serious impact on the livelihood of many people in sub-Saharan Africa that rely on cassava as their main and often only food (Hillocks et al., 1996).

Watermelon production has been greatly impacted in southern Florida since 2003 when symptoms of a severe watermelon vine decline (WVD) were observed eventually killing plants when the crop approached first harvest (Roberts et al., 2005). Yield losses were very high and could reach 50–100 % in affected fields. The disease produced by SqVYV has occurred at epidemic levels in south-west and south central Florida with losses to growers estimated at more than USD 60 million (Huber, 2006).

3.1.8.2. Situation in the risk assessment area

After its first description as a pest of tobacco in Greece (Tay et al., 2012), *B. tabaci* was reported from Spain in the 1940s (Gómez-Menor, 1943, in Guirao et al., 1997a, b) but reached status as a major pest in Europe only at the end of the 1980s. In northern Europe, including the United Kingdom, the Netherlands, France and Germany, the first reports of damage caused by *B. tabaci*, most likely from the MEAM1 species, date back to 1987–1988 (Cuthbertson et al., 2011). The insects were introduced into Europe with imported ornamentals (mainly poinsettias) (Cuthbertson et al., 2011). In the early 1990s, MEAM1 became well established in southern European countries, mainly Italy, Greece (Crete) and Spain (Cuthbertson et al., 2011).

Currently, the most widespread and predominant *B. tabaci* reported from Europe and particularly associated with serious damage on tomato and cucurbits are MEAM1 and Med (Arnó et al., 2009).

TYLCD is a serious threat to tomato production in all warm and temperate regions of the world. While many begomoviruses can cause similar diseases (Appendix B), four species, TYLCV, TYLCSV, TYLCMaV and TYLCaXV occur in the RA area and contribute to the disease, making TYLCD the most devastating and serious disease of tomato in coastal Mediterranean regions of Europe.

Although the economic impact of diseases caused by criniviruses, such as CYSDV and ToCV, is not assessed in detail, high yield reductions can be assumed based on the information from Lebanon and the United States, although disease outbreaks are less predictable and less frequent (Abou-Jawdah et al., 2000; McGinley, 2008). When CVYV struck the cucurbit industry in Spain in 2004, the extent of the economic losses prompted the government to declare compensatory measures (MAPA, 2004). Similarly, the recent appearance of BnYDV in Spain caused many farmers to abandon fresh bean production (Navas-Castillo et al., 2011).

Although virus diseases caused by *B. tabaci*-transmitted viruses result in yield losses that are generally considered severe, most of the NPPOs responding to the EFSA questionnaire indicated that there were

no or minimal problems associated with diseases from those viruses (Appendix D, Table D.2). Although a number of MSs expect moderate to severe problems with *B. tabaci* in the future (Appendix D, Table D.3) only three NPPOs from MSs responding to the questionnaire expect moderate problems with TYLCV (Appendix D, Table D.6).

3.1.8.3. Conclusion on pest status

With the emergence of MEAM1 worldwide and in Europe in the late 1980s, and the global invasion of MEAM1 subsequently followed by Med, *B. tabaci* has reached the status of one of the most important agricultural pest worldwide. This is mainly due to its significance as an efficient virus vector transmitting some of the most devastating viruses infecting important food crops. While begomoviruses causing TYLCD are considered the most serious viruses, newly emerging viruses from other genera also cause very serious diseases in tomato and pepper as well as in cucurbit crops.

3.1.8.4. Uncertainties on the pest status

Wherever *B. tabaci* is present in crop production systems it is considered an important pest. However, from all species currently described only MEAM1 and Med are also considered as being invasive. Because *B. tabaci* is a complex of closely related genetic entities (De Barro, 2012) it is not possible to predict the invasive potential of other members of the species complex. Thus, there is uncertainty concerning the invasiveness of *B. tabaci* species other than MEAM1 and Med. There are no biological characteristics to explain why some species or populations of *B. tabaci* are invasive while others are not. Severe outbreaks have been reported outside Europe for some species of the *B. tabaci* complex that are different from MEAM1 and Med. These outbreaks may result from invasion of the same genetic but geographically isolated group (e.g. Asia I) leading to genetic introgression between the invader and the local, rather than displacement of the endemic populations. Also increased population density of one over the second *B. tabaci* population, which is probably driven by host plant preferences (Sseruwagi et al., 2006), can also have effects on the relative abundance of populations already present. Thus, it remains unclear whether *B. tabaci* species other than MEAM1 and Med would also have an invasive potential, and whether their establishment and spread are only impeded/prevented because the pathways for entry are missing. For instance, nine different Asia II species have so far been described (De Barro et al., 2011; Liu et al., 2012b) only in Asia. Their invasiveness remains poorly described, although they might represent a potential threat for the RA area.

Thus, there is uncertainty over whether the introduction of other members of the *B. tabaci* complex presents a risk as potential invaders once access to a pathway is provided.

TYLCD in Europe is caused by four different begomovirus species and their strains, of which TYLCV is the most predominant in Europe and worldwide. Many other begomovirus species causing very similar tomato virus diseases have been reported from around the world and, in their particular environments, they cause serious diseases. It can thus be assumed that tomato-infecting begomoviruses present in tomato-growing regions outside Europe will also cause serious tomato diseases with significant impact on European tomato production once they enter Europe. However, there is uncertainty over whether the course of the diseases would be substantially different from those of the presently occurring TYLCD.

As shown for the four TYLCV species in Europe, of which two are a result of intraspecies recombination, begomoviruses have the capacity to recombine as, but also to transreplicate, satellite DNAs (currently not found in Europe) which results not only in novel viruses but also in more severe diseases. There is also uncertainty over whether recombinant viruses causing serious disease symptoms also possess enhanced fitness to eventually displace existing TYLCV, as was reported for the recombinant *East African cassava mosaic virus-UG* (Legg and Fauquet, 2004). Similarly, while DNA satellites can also be transreplicated by TYLCV, resulting in increased disease severities (Sivalingam and Varma, 2012; Ueda et al., 2012; Zaffalon et al., 2012), it is unclear how these

interactions come about and whether they remain stable. There is also uncertainty on the capabilities of begomoviruses reported from other plants to infect tomato and cucurbits.

The pest status of the non-circulatively transmitted RNA virus is demonstrated. Although some cause minor disease (e.g. CPMMV) with limited impact, others cause very serious diseases (CYSDV, CVYV) not only in tomato and cucurbits but also in potato (ToCV) (Freitas et al., 2012). Many viruses are only recently emerging and thus information is pending on their fate in the environment, (e.g. alternative hosts) to define establishment in nature and to explain and predict outbreaks. A number of viruses, such as ToCV, sometimes cause only mild and inconspicuous symptoms. This leaf yellowing or chlorosis can be confused with symptoms of nutritional disorder, hence new viruses as well as existing viruses can easily be overlooked and thus not identified and recognised.

3.1.9. Regulatory status

B. tabaci and the viruses transmitted by it are regulated in the EU by Council Directive 2000/29/EC on protective measures against the introduction into the Community of organisms harmful to plants or plant products and against their spread within the Community. The regulation of *B. tabaci* makes a distinction between non-European and European populations.

Non-European *B. tabaci* populations are listed in Council Directive 2000/29/EC, Annex I, Part A, Section I as "harmful organisms whose introduction into, and spread within, all Member States shall be banned". Annex IV, Part A, Section I of the same Council Directive lists specific import requirements for certain plants in connection with non-European *B. tabaci* populations.

European *B. tabaci* populations are listed in Annex I, Part B of the Council Directive 2000/29/EC as "harmful organisms whose introduction into, and spread within, certain protected zones shall be banned". Annex IV, Part A, Section II of the same Council Directive outlines specific requirements for the internal movement of plants of *S. lycopersicum* in connection with *B. tabaci* and the TYLCV. Annex IVB of this Council Directive includes specific requirements for the movements of certain plants, into and within protected zones for European *B. tabaci* populations.

Viruses transmitted by *B. tabaci* are listed in Annex I, Part A, Section I of Council Directive 2000/29/EC as "harmful organisms whose introduction into, and spread within, all Member States shall be banned". Annex IV, Part A, Section I of the same Council Directive lists specific import requirements for certain plants in connection with these viruses which differ depending on the presence or absence of *B. tabaci* or other vectors at the place of origin.

The details of the specific requirements as stated in Council Directive 2000/29/EC are provided in Appendix A.

3.1.10. Potential for establishment and spread in the risk assessment area

3.1.10.1. Factors favouring establishment

Suitable host plants: As previously described (Section 3.1.4 and Appendix B), the range of host plants of *B. tabaci* includes more than 1 000 species belonging to more than 100 botanical families (Bayhan et al., 2006b; DAF-GWA, 2008; Simmons et al., 2008; Abd-Rabou and Simmons, 2010; Li et al., 2011a). This list of confirmed or potential host plants is continuously enlarging.

To limit the phytosanitary risk, it is advisable to consider all new plant species on which *B. tabaci* is intercepted as putative host plants for this insect when other species in the botanical genus and/or family have been confirmed as host plants for *B. tabaci*. This holds true until the presence/absence of the link between this pest and the respective plant species has been scientifically demonstrated.

Many of the major host plants (Appendix B) on which *B. tabaci* can feed and reproduce are economically important crops and particularly widespread in Europe, cultivated in either protected

agricultural systems and/or in open fields (e.g. tomato, courgette, aubergine, hibiscus, poinsettia), or widely distributed in open fields in the case of weeds and some ornamentals (e.g. lantana). Consequently, host plants suitable for feeding and reproduction of *B. tabaci* are widely available throughout the year and thus do not present a limiting factor for the establishment and spread of this insect in Europe.

Temperatures: As a poikilothermic organism (i.e. an organism having a body temperature that varies with the environment), most of the biological parameters (e.g. rate of development, fecundity and survival) of *B. tabaci* are influenced by the ambient temperature (Table 4 and Appendix B).

Table 4: Biological parameters used to describe the pest potential of *B. tabaci* MEAM1 and Med

References (country) Host plants	BIOLOGICAL PARAMETERS								
	Development time (days) MEAM 1 > or < Med				Survival (%) MEAM 1 < Med	Adult longevity (days) MEAM 1 > or < Med		Fecundity MEAM 1 > Med	
	19-21°C	25-26°C	28-30°C	31-35°C	25-26°C	20°C	30°C	20°C	30°C
Iida et al., 2009 (Japan) Cabbage, Cucumber, Tomato, aubergine,, Bell pepper, Kidney beans		23.3±1.8 */ 28.1±3.6			64.8±34.6/ 77.4±13.1				
Tsueda and Tsuchida, 2011 (Japan) Tomato, Cucumber	39.3±0.8/ 40.0±4.1	20.7±1.3/ 28+1.5	16.9±1.6/ 17.6+2.3			25.4±1.8/ 22.6+1.6	11.7±0.4/ 11.5±0.1	133.9±39.8/ 108.6+39.8	131.9±5.6/ 69.4±11.7
Muñiz and Nombela, 2001 (Spain) Sweet pepper	36.6/34.1	21.5/20.7	18.0/16.2	16.8-19.8/ 16-18.1					
Muñiz, 2000a (Spain) <i>Solanum nigrum,</i> <i>Datura stramonium</i> <i>Malva parviflora,</i> <i>Capsella bursa-pastoris</i> <i>Brassica kaber</i> <i>Lactuca serriola</i>		22.6±1.1/ 21.1±1.2			50.2±23.3/ 54.3+24.5				

Notes: Values in bold correspond to MEAM1
Development time and survival are given from egg to adult
Fecundity = total number of eggs per female
Values are mean ± standard error
*No development on some host plant varieties

Development from egg to adult, survival and fecundity vary according to a range of temperatures from 10 °C to 35 °C. The lower and upper thermic thresholds for development from egg to adult are 5–6 °C and 39–41 °C, respectively (Muñiz and Nombela, 2001; Bonato et al., 2007; Deschamps and Bonato, 2011). The development time ranges from about 15–70 days and the survival from egg to adult stages from 30 % to 90 %, depending on the temperature (De Barro, 1995; Dalmon, 2007; Bonato et al.,

2007; Deschamps and Bonato, 2011). The optimal temperature for *B. tabaci* is 25–27 °C but, as reported in populations from southern Spain and France (Muñiz and Nombela, 2001; Bonato et al., 2007), higher thermic optima can be reached (i.e. 31–32 °C).

A recent study (Deschamps and Bonato, 2011) has shown that a Med population from southern France survived at –5 °C for four nights. This tolerance to low temperatures guarantees survival of the species outdoors at the winter temperatures prevailing in regions of southern France. Tolerance of Med to extreme heat was also demonstrated (i.e. 35 °C), further highlighting the potential of Med for proliferation under climatic change conditions (Deschamps and Bonato, 2011). In this scenario, a first generation of Med populations in France would appear earlier in the tomato cropping season and then generation length would be shortened so that four instead of three generations per year would develop, resulting in an increase in population densities (Fargues et al., 2006). At extreme temperatures (i.e. 35 °C) the population development of Med was considerably higher than that of MEAM1 (Bonato et al., 2007), further illustrating that temperature response and adaptation varies between species and even populations (Drost et al., 1998; Muñiz, 2000b; Muñiz and Nombela, 2001; Dalmon, 2007).

B. tabaci has a high reproductive potential and each female can lay an average of 80 to more than 300 eggs during her lifetime. The number of eggs laid depends on temperature and the host plant, but generally under favourable conditions (e.g. tomato production in greenhouses) even the introduction of only a very few founding insects will lead to a massive upsurge in insect densities (Arnó et al., 2009). Under these conditions, four to five insect generations per year can develop.

Viruses cause systemic infections in susceptible plants and, because viruses are obligate pathogens, hence they depend on a living host, it can be assumed that virus infections persist as long as the host is alive. The majority of viruses transmitted by *B. tabaci* are reported from food crops, tomato, pepper and cucurbits and those are widely cultivated in open fields and protected cultivation as well as under greenhouse conditions in southern and northern Europe, respectively. Favourable conditions for cultivation of these crops (warm climates) also favour virus infections. Once an infection has established in a particular host plant, it persists, although virus replication is considerably reduced at low (< 20 °C) and very high temperatures (> 35 °C) which are also not optimal for crop production. Because viruses transmitted by *B. tabaci* are not seed transmitted, virus infections of seasonal crops end with the removal of the plants. Virus establishment in the environment thus requires perennial, susceptible host plants acting as virus reservoirs and sources for new virus infections.

Most viruses considered in this RA have narrow host ranges mostly restricted to plant species related to the crop, e.g. cucurbit viruses infect melon, squash, cucumber and courgette. For TYLCV the most significant begomovirus in Europe, a number of plant species occurring in nature have been identified that serve as hosts for overwintering and to start new infection cycles in seasonal crops (Papayiannis et al., 2011). New cycles of virus infections then begin with the planting of infected plants, e.g. from nurseries, or with virus transmitted by viruliferous *B. tabaci*. Establishment of *B. tabaci*-transmitted viruses thus depends on suitable host plants, which might only temporarily be available in northern Europe. The establishment of viruses is also associated with the presence of *B. tabaci* to infect new plants, otherwise the virus would vanish with the death of its host.

3.1.10.2. Factors favouring dispersion

The immature stages of *B. tabaci* are sessile, except for the first nymphal instar, also called “crawlers” which may move a few centimetres in search of a feeding site. The first nymphal stage only exceptionally moves to other leaves on the same plant (Byrne and Bellows, 1991). Active movement to other plants, fields or areas can only be made by adults.

Directional and active flights of *B. tabaci* adults are limited. The effective distance of migration (i.e. the distance to which insects can fly and establish new colonies) has been estimated to be a maximum of 7 km in a 12-hour period for *B. tabaci* found in plantings of cantaloupes, *Cucumis melo* L. (Byrne, 1999), and 2.5 km for the MEAM1 *B. tabaci* (De Barro, 1995). Information on the flight capacity of

other *B. tabaci* species is not available. Limited flight capabilities, however, are not a limiting factor to dispersal because, with the wide range of putative hosts, suitable plants are mostly available. Furthermore, in agro-ecosystems, especially under intensive production, suitable host plants, densely spaced, are found within a short distance. Under protected cultivation, plant production is throughout the year and suitable crops follow and rotate at tight intervals, favouring the establishment and dispersal of *B. tabaci*. Whitefly adults can migrate over long distances *via* passive transport with wind. These “long-distance flights” happen when adults on host plants get trapped in wind streams. Massive clouds of passively dispersing *B. tabaci* were observed in cotton in the United States during the 1990s (Naranjo et al., 2010). Notwithstanding this, the key element favouring dissemination of *B. tabaci* is movement through trade of large quantities of plants (see Section 3.2), mostly of ornamentals. As has been shown from many interceptions, new pest records and outbreaks of *B. tabaci* around the globe, the trade in ornamental plants constitutes a very efficient means for long-distance transport of eggs, nymphs and adult whiteflies and is a key factor in the *B. tabaci* invasion process.

The spread of *B. tabaci*-transmitted viruses is by virus-infected plant materials and viruliferous insects transmitting viruses to infect new hosts. In areas where viruses and *B. tabaci* vector insects are established in open fields, the transfer of viruses to crops is inevitable. Virus spread is favoured by active adult whiteflies visiting many plants and boosted by high numbers of insects efficiently transmitting the disease. Once a virus disease is established in a plant, this plant then acts as resource for new infections, thus infections of only a few infested plants can result in serious epidemic outbreaks. Differences in transmission capabilities are reported for MEAM1 and Med; however, not all reports arrive at similar conclusions. Sánchez-Campos et al. (1999) and Pan et al. (2012) found that the transmission of TYLCV from tomato to tomato was significantly higher with Med when compared with MEAM1, while Liu et al. (2010a) were not able to confirm differences among the two species. Notwithstanding this, while differences in transmission efficiencies might exist between *B. tabaci* species, high numbers of *B. tabaci* favour virus spread even of viruses such as ipomoviruses that are not readily transmitted. An abundance of *B. tabaci* and high concentrations of virus in a host contribute similarly to the efficiency of virus transmission and spread.

Young plants are most susceptible to virus infections, and increasing resistance with age often prevents successful plant infection. For TYLCV, it has been shown that tomato plants in nurseries, before transplanting, often suffer very severe infections. The spread of begomoviruses depends on *B. tabaci* and, once ingested, those insects remain viruliferous for their entire life. Thus spread over long distances can be sustained with viruliferous whiteflies on plant commodities and virus-infected suitable hosts are not required.

Long-distance spread of NVs by viruliferous whiteflies alone is very unlikely because the virus is rapidly lost when whiteflies suck on plants that are not susceptible to viruses. For plant infection, these viruses rely on *B. tabaci* vectors (some species are also transmitted by *Trialeurodes vaporariorum*); long-distance spread, however, is bound to infect plants susceptible to the virus(es). This is best shown by the almost simultaneous appearance of the newly emerging ToTV in several European countries and around the world, connected by trade pathways (Gomez et al., 2012).

3.1.11. Potential for consequences in risk assessment area

B. tabaci causes direct damage through feeding on phloem and significant indirect damage through transmitting numerous harmful plant viruses, mainly begomoviruses, on a wide range of vegetable and ornamental crops, grain legumes and cotton in both open fields and greenhouses (Bedford et al., 1994; Oliveira et al., 2001; Jones, 2003).

Direct feeding damage is caused by piercing and sucking of sap from the foliage of plants. Heavy infestations of adults and immature stages can cause seedling death, or a reduction in the vigour of older plants, simply due to sap removal. Feeding also causes weakening and early wilting of the plant and reduces the plant growth rate and yield (Berlinger, 1986). Furthermore, it may cause leaf chlorosis, leaf withering, premature dropping of leaves and plant death. Infestations by whitefly

nymphs, in particular the MEAM1 *B. tabaci*, are associated with phytotoxicity disorders, such as the irregular ripening of tomatoes (TIR) and squash silverleaf disorder (SSD) (Yokomi et al., 1990; Hanif-Khan et al., 1996).

Indirect feeding damage results from the accumulation of honeydew, a sticky excretory waste that is composed largely of plant sugars, produced by adult and immature whiteflies. This honeydew serves as a substrate for the growth of black sooty mould on leaves and fruits. The mould reduces photosynthesis and decreases the yield and market value of the vegetables and fruits and the aesthetic quality of ornamentals (Byrne and Bellows, 1991). The honeydew can stick cotton lint together, making it more difficult to gin and therefore reducing its value.

Major damage is caused by transmission of a large number of diverse viruses when feeding on plant phloem. *B. tabaci*-transmitted plant viruses infect some of the most important agricultural crops and cause symptoms that can be described as leaf mosaic (New World begomoviruses), leaf curl (Old World begomoviruses), interveinal leaf yellowing (criniviruses), leaf mosaic and deformation (carlaviruses), vein yellowing (ipomoviruses), and leaf necrosis (torradoviruses). Begomoviruses of which more than 300 species are currently known (Brown et al., 2012), cause serious diseases and those viruses involved in TYLCD are the most damaging. In areas where *B. tabaci* is established, tomato cultivation is almost inevitably associated with TYLCD and in many areas crop management is impossible under open field conditions. Early TYLCV infections lead to drastic reductions in plant growth, a bushy appearance of the apical parts of the plant, leaf curling and deformation and abortion of flowering. Infection at early stages in plant development, that is before the first flowering, mostly lead to a total loss of the crop while infections at later stages have less severe consequences and fruit production is reduced but not repressed. The TYLCV established in the RA area can be considered to be the most invasive begomovirus species as this virus is very efficiently transmitted by MEAM1 and Med to tomato, pepper and bean crops, rendering TYLCD one of the main limiting factors to tomato production in open fields and protected production sites around the world.

Three of the principal horticulture plant families in Europe, the Solanaceae, the Cucurbitaceae, and the Leguminoae can be infected by member species of the family *Crinivirus*: ToCV, CYSDV and BnYDV respectively. The symptoms are typically interveinal yellowing of leaves from the middle to the lower parts of plants, and are associated with fruit yield losses. In Brazil, where tomato and potato are grown in open fields, ToCV recently has been shown to infect potato causing a disease similar to potato leafroll virus disease (Freitas et al., 2012). Thus, it can be assumed that once transmission has occurred, ToCV will establish in this crop. Ipomoviruses produce leaf symptoms consisting of vein yellowing in apical leaves and, depending on the affected plant species, necrosis of fruits (Cuadrado et al., 2001; Louro et al., 2004). Whereas CVYV is present in the RA area, SqVYV was only recently described from the United States causing a serious vein yellowing in squash and watermelon, and vine decline, collapse and plant death in the case of watermelon (Adkins et al., 2007).

Torradoviruses, and its type species ToTV produce symptoms in tomato plants expressed as necrotic lesions at the base of the leaflets, longitudinal necrotic lesions on the stems, and necrotic line patterns or blotches followed by deformations on the entire plant with substantial losses reported for tomato in Guatemala.

B. tabaci-transmitted carlaviruses such as CPMMV (Iwaki et al., 1982) and MYaV (Nagata et al., 2003) are described from cowpea (Ghana), soybean (Kenya, Nigeria, and Ivory Coast), groundnut (India), tomato (Israel) and bean (Brazil, North Africa) for CPMMV and MYaV from melon respectively. Leaf symptoms are often mistaken for nutritional disorders, and infected plants can suffer fruit deformation or loss of fruit yield. Economic losses are not reported (Reddy and Rajeshwari, 1984; Hall, 1991; Nagata et al., 2003).

3.1.12. Conclusion on pest categorization

B. tabaci is considered to be one of the most serious threats to crop cultivation worldwide, predominantly because of the large number of viruses it transmits. In regions where *B. tabaci* is established viruses transmitted by this insect, especially those affecting tomato and cucurbits and also beans, peppers and aubergines are responsible for severe diseases with a strong negative impact on crop yield. As a consequence, crop production in those areas is not possible without a system-wide and comprehensive set of pest and disease management measures in place. In the RA area, *B. tabaci* is present outdoors in coastal areas with a Mediterranean climate, and in many EU countries the pest is present in greenhouses.

B. tabaci is a complex of at least 28 indistinguishable morphocryptic species of which four occur in Europe. Two species, Mediterranean (Med, formerly referred to as biotype Q) and Middle East–Asia Minor 1 (MEAM1, formerly referred to as biotype B) are mostly associated with negative effects on crops such as ornamentals, tomato and cucurbits, and are prevalent both in Europe and in many regions across the world. Many other *B. tabaci* species exist outside the RA area and those can reach high population densities, but it is only Med and MEAM1 that are considered invasive. All *B. tabaci* species can transmit viruses, and viruses associated with *B. tabaci* reported from around the world have an immense diversity that is reflected in numerous species and strains. In general, diseases resulting from virus infections have a serious negative impact on crops and, thus, the introduction of *B. tabaci*-transmitted viruses currently not present in the EU would be a significant risk.

3.2. Probability of entry

The Panel identified the following pathways for the entry of *B. tabaci* (non-European populations) and the viruses it transmits in the RA area:

1. Plants for planting including cuttings and rooted ornamental plants originating from areas where non-European populations of *B. tabaci* occur;
2. Cut flowers and branches with foliage originating from areas where non-European populations of *B. tabaci* occur;
3. Fruits and vegetables, including leafy herbs for consumption originating from areas where non-European populations of *B. tabaci* occur;
4. Human-assisted spread of non-European *B. tabaci* populations not associated with plants (e.g. on vehicles or clothes);
5. Natural spread of non-European *B. tabaci* populations (e.g. by wind).

Spread of *B. tabaci* by means of human activities (pathway 4) not directly associated with plants and the plant trade may occur over long distances within the EU area. However, it is unlikely that such rare events will lead to the introduction of *B. tabaci* from outside Europe (see RRO 4.4.17). Similarly, whitefly adults can migrate over long distances via passive transport with wind (pathway 5). Notwithstanding this, the main dissemination pathway of *B. tabaci* is with the trade of large quantities of plants (see Section 3.2), and thus pathways 4 and 5 were considered negligible. The Panel considered pathways 1, 2 and 3 as the most important and analysed them in detail.

Selection of the most important pathways

In this opinion, the most important pathways for further assessment were selected following the EFSA guidance on a harmonised framework for pest risk assessment and the identification and evaluation of pest risk management options (EFSA Panel on Plant Health (PLH), 2010). It states that (i) “the most relevant pathways should be selected using expert judgment and, where there are different origins and end uses, only realistic worst-case pathways”, and (ii) “closed pathways may be considered, as the pests identified may support existing phytosanitary measures. Furthermore, some pathways may be closed by phytosanitary measures which might be withdrawn at a future date. In such cases, the risk assessment may need to be continued.”

B. tabaci is one of the most commonly intercepted pests on a wide range of commodities entering the RA area with trade. According to the EPPO Reporting Service (EPPO, 2012a), *B. tabaci* has accounted for one-third of all non-compliance reports in the period 2006–2010 concerning plants for planting including cuttings, with the highest number of reports from interceptions on Euphorbiaceae and aquatic plants. The numerous interceptions may be due to the wide geographical distribution of *B. tabaci*, its extreme polyphagy and the fact that the insect is familiar and readily identified. Considering interception reports from France between 1997 and 1999, the number of infested consignments from third countries is increasing (130 findings in 1997 and more than 300 records from 19 countries in 1999). The greatest diversity of commodities with records of *B. tabaci* originated from Israel, whereas infested consignments from Singapore only comprised aquatic plants (Bayart et al., 2001).

The main factors contributing to the recent increase in pest movement and introduction were attributed to increased volumes and types of commodities of traded plants and plant products, the globalisation of trade with commodities from diverse origins, changes in production areas, difficulties in identifying the risks posed by pests and difficulties in taking appropriate action, combined with the limited efficiency of inspections when large volumes have to be investigated (EPPO, 2012a).

The relevant pathways for entry of *B. tabaci* and the viruses it transmits concern only the import of plant commodities from third countries, as it is presumed that non-European *B. tabaci* populations would not be found on plants and plant products originating in the RA area. Introduction into and spread within the EU of such populations is prohibited by Council Directive 2000/29/EC (Annex I, Part A, Section I), and specific requirements for the introduction of host plant commodities into the EU are formulated in Annex IV of Council Directive 2000/29/EC.

For pathway 1 (plants for planting), for non-European countries the absence of *B. tabaci* in the area of production or at the place of production is required (Annex IV, Part A, Section I, point 45.1 of the council Directive 2000/29/EC). For all countries, including those European countries that are not EU MSs, where *B. tabaci* is known to occur, similar measures (absence of *B. tabaci* in the area of production or at the place of production) have been formulated for:

- plants of *S. lycopersicum* intended for planting, other than seeds, originating in countries where TYLCV is known to occur

and for

- plants intended for planting, originating in countries where viruses transmitted by *B. tabaci* are known to occur.

Because of these requirements this pathway is theoretically closed for entry of *B. tabaci*, and hence also for viruses transmitted by *B. tabaci*.

For pathway 2 (cut flowers and branches with foliage), either absence of *B. tabaci* in the country of production or absence in the consignment immediately prior to export is required (Annex IV, Part A, Section I, point 45.2 of Council Directive 2000/29/EC). This, however, applies to a limited range of host plant species.

These measures strongly rely on visual inspection of consignments, while the efficacy for detection of all stages (adults, nymphs, eggs) of *B. tabaci* in consignments cannot be 100 %, and only a few species of host plant species are addressed. Therefore, this pathway cannot be considered as closed for *B. tabaci*. There are no special requirements to confirm the absence of viruses that may be transmitted by *B. tabaci* in the area or at the sites where cut flowers and branches with foliage are produced. However, ornamental species, with only a few exceptions, are not considered host plants for viruses transmitted by *B. tabaci*, and therefore this pathway is considered to be of minor importance for such viruses.

For pathway 3 (fruits and vegetables intended for consumption) only the leafy vegetable *Ocimum* L. (generic basil) is covered by the regulation, with measures as for cut flowers formulated. (Annex IV, Part A, Section I, point 45.2). As many species of fruit and vegetables are putative hosts of viruses transmitted by *B. tabaci*, this pathway is not closed, neither for *B. tabaci* nor for the viruses it transmits.

The numerous interceptions of *B. tabaci* on commodities originating from third countries in 1993–2011 (EUROPHYT, Table 5) provide evidence that indeed pathways 1, 2 and 3 are not closed. The interceptions are almost evenly distributed over the different commodity types, with 29 % of all interceptions in consignments of plants for planting. This provides evidence that mandatory measures to establish pest-free areas or places of production including eradication at infested production places, required for plants for planting, can be difficult to implement.

No data on the presence of viruses transmitted by *B. tabaci* are recorded for intercepted consignments. This is because import inspection relies on visual examination of consignments, and symptoms suspicious for virus diseases can be difficult to interpret even in susceptible hosts. Detection of viruses would require regular use of diagnostic tests for virus detection and identification in plants or *B. tabaci* insects. These detection methods, however, are not commonly used in inspection services.

Table 5: Interceptions of *B. tabaci* on plant commodities originating from third countries for the period 1993 – 2011 (Source: EUROPHYT)

Commodity	Number of interceptions	Percentage of total number of interceptions (%)
Plants for planting	1184	29%
Fruit and vegetables	1574	38%
Cut flowers and branches with foliage	1381	33%
Total	4139	

Fruits and vegetables represent a pathway that currently is largely unregulated, with the exception of leafy vegetables of *Ocimum* sp. and *Apium* sp.

For the purposes of this assessment, the Panel has considered the expert opinion and factual information (trade data, presence/absence of *B. tabaci* and the viruses it transmits) as specified in Section 2.1.3. Interception data from EUROPHYT for the period 1993–2011 (Table 5) have also been considered.

3.2.1. Plants for planting including cuttings and rooted ornamental plants

3.2.1.1. Probability of the pest being associated with the pathway at origin

B. tabaci is a polyphagous pest that infests a wide range of plant species (host plants) but beyond that insects can also be carried along on non-host plants, that is with plants on which the insect is only visiting or probing. Consequently, entry of *B. tabaci* can be expected with plant consignments originating from all areas around the world where populations of this insect are established.

EPPO (2012a) conducted a detailed analysis of trade in plants for planting provided by the Netherlands, Germany, France and Italy (the main trade countries in the EC) for the period 2006–2010. The data relate to plants mainly of non-EU origin for which phytosanitary certificates are required. In 2010, over 50 600 consignments containing more than four billion units of plants for

planting were imported of which approximately 3.5 billion units were destined for the Netherlands (EPPO, 2012a) alone. The most traded genera and families were Asteraceae (over 54 % of the total numbers). On those consignments *B. tabaci* was most frequently intercepted with the highest number of interceptions found on *Euphorbia* spp. of which more than 118 million units are traded (EPPO, 2012a). EUROSTAT data for 2008–2010 confirm a considerable volume of trade of plants for planting from third countries to the EU, amounting to approximately 98 000 tons per year. The commodities originate mainly from Asia (30 622 tonnes), South America (28 475 tonnes) and North America (18 222 tonnes) (Appendix C).

Over the past 19 years, 1 184 interceptions of *B. tabaci* on plants for planting originating from third countries have been recorded in the EU (Table 5). On average, 60 interceptions/year were made and consignments from Singapore and Israel (Table 6) received most complaints. With 50 000 imported consignments of plants for planting (data for 2010) this suggests that an average of 0.1 % of imported consignments is infested with *B. tabaci*. Aquatic plants generated approximately 40 % of all notifications for plants for planting. These are traded in very high volumes and comprise more than 250 species originating mostly from south-eastern Asia and Africa (Table 7).

Although Annex IV of Council Directive 2000/29/EC covers all herbaceous species, given the numerous interceptions of *B. tabaci* on aquatic plants, special consideration of those genera is warranted. Explicit requirements for plants for planting of the genera *Hygrophila*, *Alternanthera*, *Limnophila*, *Echinodorus*, *Anubias*, *Bacopa* and *Hemigraphis* would significantly reduce the risk of entry of *B. tabaci* by this pathway.

Table 6: Interceptions of *B. tabaci* on plants for planting originating from third countries for the period 1993–2011, sorted by country of origin

Country of origin	Number of interceptions		Period	
	Absolute	Relative to “Plants for planting” (%)	From	To
Singapore	331	28	1998	2011
Israel	295	25	1993	2011
Kenya	94	8	2000	2011
Thailand	59	5	1998	2011
Sri Lanka	55	5	1995	2011
Canary Islands	35	3	1998	2010
USA	30	3	1994	2011
Morocco	29	2	1997	2004
Malaysia	28	2	1998	2008
Cote d'Ivoire	23	2	1996	2011
Tunisia	22	2	1994	2010
Vietnam	22	2	2000	2011
Ethiopia	18	2	2006	2011
Indonesia	16	1	1999	2011
Brazil	12	1	1994	2011

There is also uncertainty regarding the suitability of aquatic plants as hosts for *B. tabaci* as it is also unclear whether imported aquatic plants are further cultivated and what methods are used for this. *B. tabaci*-transmitted viruses are not known to infect aquatic plant species and it can be considered that aquatic plants do not represent a pathway for their introduction.

The imported plant species are very diverse, while in many cases the official data provide information only on commodity level (e.g. ornamentals) which adds uncertainty about the actual species being imported into and moving within the EU.

Table 7: Interceptions of *B. tabaci* on plants for planting originating from third countries for the period 1993-2011, sorted by plant species / genera (over 10 interceptions).

Genus/Species	Number of interceptions	
	Absolute	Relative to “Plants for planting” (%)
<i>Hygrophila</i> spp.* (<i>H. angustifolia</i> ; <i>H. difformis</i> ; <i>H. polysperma</i> ; <i>H. rosanervis</i> ; <i>H. salicifolia</i> ; syn. <i>Nomaphila costata</i> ; <i>N. siamensis</i> ; <i>Ruellia difformis</i>)	215	18
<i>Euphorbia</i> spp.	189	16
<i>Alternanthera</i> sp.*	63	5
<i>Limnophila</i> sp.*	59	5
<i>Hibiscus</i> spp.	51	4
Acanthaceae (as <i>Hypoestes</i> etc.)	38	3
<i>Echinodorus</i> sp.*	32	3
<i>Mandevilla</i> sp.	27	2
Aquarium plants—unknown spp.	24	2
<i>Anubias</i> sp.*	22	2
<i>Lantana camara</i>	21	2
<i>Verbena</i> sp. (including hybrids)	21	2
<i>Ajuga</i> sp.	20	2
<i>Crossandra</i> sp.	20	2
<i>Fuchsia</i> sp. (incl. hybrids)	19	2
<i>Salvia officinalis</i>	19	2
<i>Bacopa</i> sp.*	18	2
<i>Hemigraphis</i> sp.*	16	1
<i>Lantana</i> sp.	15	1
<i>Myrtus</i> sp. (incl. <i>communis</i>)	12	1
<i>Cryptocoryne</i> sp.*	11	1
<i>Ludwigia palustris</i> **	11	1
<i>Artemisia drancunculus</i>	10	1

*Species/genera are aquatic plants and are used as aquarium plants

Viruses are associated with the pathway at origin as most trade concerns countries where viruses are abundant. The major volume of trade in this pathway mainly concerns ornamental plants. Most of the specific ornamental plant species that are imported via this pathway are non-host plants for *B. tabaci* -transmitted viruses. As consequence the majority of viruses will be transferred by viruliferous *B. tabaci*. Entry of circulatively transmitted viruses is with viruliferous *B. tabaci* insects. Because of their limited persistence in their vectors non-circulatively transmitted viruses can enter only with infected host plants. Entry of viruses with viruliferous *B. tabaci* (circulatively transmitted viruses) or with infected crop plants (non-circulatively transmitted viruses) is considered as moderately likely. Medium uncertainty exists on unknown viruses carried from the environment with whiteflies. For viruses transmitted by *B. tabaci* there is uncertainty whether newly introduced ornamental plant species including aquatic plants can be new host plants for hitherto unknown viruses.

3.2.1.2. Probability of survival of the pest during transport or storage

Development of *B. tabaci* occurs between 10 °C and 35 °C (Deschamps and Bonato, 2011). The likelihood of survival of adults is very low after six hours at 30–40 °C (Berlinger et al., 1996). Although adults are the least resistant stage at low temperatures; they can still survive at 6 °C for at least four days. This is one of the lowest temperature thresholds recommended by the United States Department of Agriculture for transportation of potted ornamental plants (Welby and McGregor, 2004). Eggs and nymphs are much more resistant to cold. Nymphs of *B. tabaci* can survive for at least eight days at 4 °C, while eggs are still able to hatch after eight days at 6 °C (Bosco and Caciagli, 1998). Lacey et al. (1999) showed that even after nine days at 5 °C a small number of viable eggs remain. During the last nymphal instar (or pharate adult stage), whiteflies do not feed (Byrne and Bellows, 1991; Gelman et al., 2002) and are resistant to desiccation, so they can survive on dry foliage (Caciagli, 2007).

Transport of plants and plant products in trade from third countries to the EU would not usually take more than a week and, presumably, the temperature in the consignment would not fall below 6 °C to prevent damage of the commodities. Thus, the pest is very likely to survive during transport or storage with low uncertainty.

Circulatively transmitted begomoviruses are likely to survive with the living insect because once acquired the insect remains viruliferous throughout its lifespan. As non- and semi-persistently transmitted viruses are lost within several hours to a few days, these viruses are not likely to survive transport and storage when *B. tabaci* infests plants that are not susceptible to virus infections. Because *B. tabaci*-transmitted viruses cause systemic infections in their host plants, viruses are likely to survive as long as the plant continues to grow.

3.2.1.3. Probability of pest surviving the existing management procedures

Entry of non-European populations of *B. tabaci* in the RA area shall be banned. The existing management procedures include inspection at the place of production and, in the case of detection, appropriate treatment to ensure freedom of the plants from *B. tabaci* prior to export. EPPO (2004) has developed a protocol, covering detection and morphological identification of *B. tabaci*. However, visual inspection of the plants is not fully reliable for the following reasons:

- 1) All life stages of *B. tabaci* are usually found on the underside of the leaves (Bedford et al., 1994).
- 2) Newly hatched eggs and young instars are transparent and small in size.
- 3) Adults, present at low densities, may remain undetected.
- 4) Misidentification with related species, such as *T. vaporariorum*, is possible.
- 5) The methods for inspection are not clearly specified in the regulations and thus might not be fully effective.

Prior to export, commodities are inspected by the NPPO of the exporting country. However, the methods for detection are not specified in Directive 2000/29/EC and therefore NPPOs may use various approaches and sampling sizes. Therefore, if the pest is present only on a few plants in a consignment or occurs at very low densities/numbers, it may still remain undetected.

Methods for treatment are not specified in the legislation and treatment with insecticides prior to shipment is problematic as not all stages of *B. tabaci* are effectively and simultaneously targeted with only one plant protection product. Low numbers of surviving individuals may evade detection during subsequent inspections. Therefore, *B. tabaci* is likely to survive the existing management procedures with moderate uncertainty.

This is also true for viruses. Along with surviving insects, circulatively transmitted viruses also survive while non-circulatively transmitted viruses are likely to get lost when *B. tabaci* is feeding on

non-susceptible plant species. Plant inspections generally check for symptoms which makes the detection of *B. tabaci*-transmitted viruses very difficult especially in early infections, when symptoms are not very pronounced or when on only few plants or absent.

3.2.1.4. Probability of transfer of the pest to a suitable host

Based on the data for import from third countries and internal movement, the commodity is very widely distributed throughout the RA area. There are no seasonal restrictions of the trade of plants for planting. *B. tabaci* can establish in greenhouses throughout the year and can overwinter outdoors in several EU countries. The pest is highly polyphagous, with more than 1 000 host plant species, including wild plants, which can serve as reservoirs (Chu et al., 2006; De Barro et al., 2011; Rao et al., 2011). In greenhouses, where planting material is usually delivered after import, *B. tabaci* can easily infest adjacent plants.

A good example to illustrate the ease with which *B. tabaci* can transfer to non-infested hosts is the trade in cuttings of *Euphorbia pulcherrima* (poinsettia), which, for the past 19 years, has accounted for the highest number of recorded interceptions of the pest. The typical method of culture of *E. pulcherrima* aids transfer to a suitable host. *B. tabaci* initially enters the RA area on cuttings, imported at the beginning of the year in order to obtain first-generation mother stock plants. One of the key factors facilitating transfer of the pest is that *E. pulcherrima* is a seasonal crop fitted in among various other crops (Fransen, 1994), many of which are hosts for *B. tabaci*. Ornamental trade, particularly the poinsettia pathway, was proposed as the main pathway of introduction (and spread) of *B. tabaci* MEAM1 and Med in the United States (Dalton, 2006) and New Zealand (Drayton et al., 2009). Therefore, the probability of transfer to a suitable host is very high with low uncertainty.

Entry of TYLCV into the United States was probably with the introduction of viruliferous *B. tabaci* on ornamentals (poinsettia) providing proof for efficient transfer to susceptible hosts (tomato) or, with infected plants (Duffy and Holmes, 2007; Polston and Anderson, 1997; Polston et al., 1999). Non-circulative viruses enter with infected plant materials and, because this mostly concerns crops, suitable host plants are available to which viruses are transmitted.

3.2.2. Cut flowers and branches with foliage

3.2.2.1. Probability of the pest being associated with the pathway at origin

The EU consumes more than half of the world's cut flowers. Six of the ten biggest national cut flower markets in the world are in the EU: the Netherlands, Germany, United Kingdom, France, Italy and Spain. In the international trade, the EU accounts for approximately 70 % of world imports (including trade between EU member states). The Netherlands supplies almost three-quarters of the EU market of cut flowers and the country's auction markets are the largest and most developed in the world (SADC Trade, online).

Based on EUROSTAT data for the period 2008–2010, the volume of movement along the pathway of cut flowers and branches with foliage from third countries to the EU is approximately 73 000 tons per year. The commodities are imported mainly from North America (38 533 tonnes), South America (19 440 tonnes) and the Near East (8 217 tonnes).

During the period 1993–2011, there were 1 381 interceptions of *B. tabaci* in consignments of cut flowers and branches with foliage originating from third countries. These account for 33 % of all non-compliances related to presence of *B. tabaci*. The infested plant commodities of this type belong to 33 different species/genera, of which the most important are *Solidago* sp. (52 %), *Trachelium* sp., *Rosa* sp., *Eustoma* sp. (*Lisianthus*), *Gypsophila* sp. and *Aster* sp. (Table 8).

The data analysis shows that some plant species that have in the past generated interception reports for cut flowers currently generate significantly more interceptions for fruits and vegetables for consumption. For example, for the period 2007–2011, infestations of *B. tabaci* on imported *Eryngium*

sp. and *Limnophila aromatica* have been recorded almost exclusively for fruit and vegetables for consumption while, prior to this period, the majority of interceptions were on cut flowers. It is unlikely that this shift in commodity class observed in the interception data is due to a rapid change in the trade of the imported species. Rather, there is uncertainty related to the intended use of such imports.

Table 8: Interceptions of *B. tabaci* on cut flowers and branches with foliage originating from third countries for the period 1993–2011, sorted by plant species/genera (with more than 10 interceptions)

Plant species/genus	No of interceptions	
	Absolute	Relative to “Cut flowers and branches with foliage” (%)
<i>Solidago</i> spp. (Incl. <i>S. canadensis</i> , <i>Solidaster hybrida</i>)	721	52
<i>Trachelium</i> sp. (incl. <i>T. ceruleum</i>)	131	9
<i>Hypericum</i> spp. (incl. <i>H. androsaemum</i> ; <i>H. Xylosteifolium</i>)	124	9
<i>Rosa</i> sp.	81	6
<i>Eustoma</i> sp. (incl. <i>E. russelianum</i>) <i>Gentianaceae</i>	73	5
<i>Gypsophila</i> sp. (<i>G. elegans</i> ; <i>G. paniculata</i>)	63	5
<i>Aster</i> sp.	58	4
<i>Hibiscus</i> sp. (incl. <i>H. sabdariffa</i>)	28	2
<i>Chrysanthemum</i> sp.	20	2
<i>Solidaster</i>	18	1
<i>Liatris</i> sp. (incl. <i>spicata</i>)	12	1

B. tabaci was intercepted in import of cut flowers and branches with foliage originating from 24 third countries. 89% of all non-compliances relate to consignments originating from Israel (81%) and Zimbabwe (8%) (see Table 9).

Table 9: Interceptions of *B. tabaci* on cut flowers and branches with foliage originating from third countries for the period 1993-2011, sorted by country of origin (with more than 10 interceptions)

Country of origin	No of interceptions		Period	
	Absolute	Relative to “Cut flowers and branches with foliage” (%)	From	To
Israel	1 118	81	1993	2011
Zimbabwe	113	8	1996	2011
Canary Islands	22	2	1999	2006
Togo	18	1	1998	1999
Thailand	16	1	1998	2006
Brazil	11	1	2004	2008

B. tabaci can enter the pathway on cut flowers with leaves such as chrysanthemum. This is relevant for all nymphal instars. This is because *B. tabaci* is highly abundant in countries producing cut flowers. Ornamental species are not known as hosts for *B. tabaci*-transmitted viruses particularly those infecting major crops, tomato, pepper and cucurbits. However, high numbers of insects from the agricultural environment likely carry viruses and thus viruses are to be expected with insects. Still, because ornamental plants species used for cut flowers (except *Eustoma* sp.) are generally not considered hosts for virus of concern, viruses are only associated with viruliferous *B. tabaci* infesting cut flowers.

3.2.2.2. Probability of survival of the pest during transport or storage

The probability that *B. tabaci* will survive during transport is likely with low uncertainty (see Section 3.2.1.2 for the pathway of plants for planting). The most resilient stages are eggs and the last nymphal instars. However, after hatching, the first instar needs to feed in order to develop, while the second stage of the last nymphal instar (pharate adults) can emerge without a food source. Survival of *B. tabaci* adults however during transport and storage is unlikely and this also has consequences for the survival of *B. tabaci*-transmitted viruses. Survival of viruses would be with viruliferous *B. tabaci* adults only because nymphal stages developing to adults on non-host plants cannot acquire viruses.

3.2.2.3. Probability of pest surviving the existing management procedures

For cut flowers of *Aster* spp., *Eryngium*, *Gypsophila*, *Hypericum* and *Lisianthus* originating in non-European countries, Council Directive 2000/29/EC requires an official inspection prior to export and a statement that these cut flowers have been found free from *B. tabaci*, unless the consignment is from a country free from *B. tabaci* (Annex IV, Part A, Section I, point 45.2). Clearly, this requirement often cannot be fulfilled, because many interceptions are still made in these commodities (Table 8). In addition, other commodities for this pathway (Annex V, Part B, point 2) require a phytosanitary certificate based on a plant health inspection prior to export (but without the statement that *B. tabaci* is absent on the plants): parts of plants, other than fruits and seeds, of *Dendranthema*, *Dianthus*, *Gypsophila*, *Pelargonium*, *Phoenix* spp. and *Solidago*, and cut flowers of Orchidaceae. This includes branches with foliage for some but not all host plant species of *B. tabaci*. In particular, branches with berries for example *Hypericum* spp. are not subject to regulation. The pest is likely to survive the existing management procedures.

Ornamental species are not known as hosts for *B. tabaci*-transmitted viruses particularly those infecting major crops, tomato, pepper and cucurbits. Begomoviruses would enter with adult *B. tabaci* insects surviving transport and storage while non-circulatively transmitted viruses would most likely have been lost during transport because of the immediate requirement for susceptible host plants, which is not the case for species used as cut flowers.

3.2.2.4. Probability of transfer of the pest to a suitable host

Cut flowers and branches with foliage are imported in considerable volumes all year round and are widely distributed in the RA area. Transfer of emerging adults of *B. tabaci* to suitable hosts can occur at open flower markets, in storage facilities and adjacent areas (e.g. on wild plants growing in the vicinity). In cases where the second stage of the last nymphal instar of the pest that does not feed is present on leaves, adults can emerge during the vase life of the flowers and disperse naturally to neighbouring suitable hosts (e.g. domestic plants, garden vegetation, etc.). Therefore the probability of transfer of the pest to a suitable host is moderately likely with low uncertainty.

A viruliferous insect can transmit viruses provided that a susceptible host is found within reach. Even though circulatively transmitted viruses would survive all phases of entry, it is unlikely that suitable hosts on which viruses can establish will be found in the close vicinity.

3.2.3. Fruits and vegetables including herbaceous plants

3.2.3.1. Probability of the pest being associated with the pathway at origin

The EU market for fruit and vegetables is one of the most attractive for potential exporters worldwide. Based on EUROSTAT data for the period 2008–2010, the volume of movement along the pathway of fruits and vegetables from third countries to the EU is approximately 16.3 million tonnes per year. About 7 million tonnes are imported from South America, while considerable volumes are also imported from Africa and North America (Appendix C)

For the past 19 years, 38 % or 1 574 of all interceptions of *B. tabaci* on plant commodities were recorded for fruits, vegetables and spices intended for consumption. The plants belong to 50

species/genera. The majority of non-compliances relate to *Ocimum* spp. (mainly *O. basilicum*) and *Eryngium foetidum*.

The analysis of the interception data shows that some plant species on the pathway generate interception records also for other pathways, i.e. have several intended uses. For example, *Manihot* sp., which is a host for *B. tabaci*-transmitted viruses can be considered as an ornamental plant while its tuberous root is a vegetable for consumption. When imported as a vegetable, *Manihot* sp. can generate interceptions of *B. tabaci* only if its leaves were not removed. Infestations of this species have been recorded on vegetables for consumption and also on leaves of this species (cut flower pathway). The pathway of fruits and vegetables is subject to less stringent legislative requirements but if the consignments of *Manihot* sp. actually contain living plants with leaves, the risk of entry of *B. tabaci* would be much greater than with import of tubers. Therefore, there is uncertainty regarding the level of risk of such imports.

Table 10: Interceptions of *B. tabaci* on fruits and vegetables, including herbaceous plants, for consumption originating from third countries for the period 1993–2011, sorted by plant species/genera (with more than 10 interceptions)

Species/genus	Number of interceptions	
	Absolute	Relative to “Fruits and Vegetables” (%)
<i>Ocimum</i> spp. (incl. <i>americanum</i> , <i>basilica</i> , <i>sanctum</i>)	593	38
<i>Eryngium foetidum</i>	427	27
<i>Manihot</i> sp. (incl. <i>esculenta</i>)	134	9
<i>Ipomoea batatas</i>	51	3
<i>Piper</i> sp. (incl. <i>sarmentosum</i>)	44	3
<i>Corchorus</i> spp. (<i>olitorius</i>)	43	3
<i>Colocasia esculenta</i>	33	2
<i>Origanum</i> sp. (<i>majorana</i> , <i>vulgare</i>)	33	2
<i>Limnophila aromatica</i>	27	2
<i>Mentha</i> spp. (incl. <i>piperita</i>)	23	1
Unknown spp	17	1
<i>Solanum melanogena</i>	16	1
<i>Artemisia dracunculus</i> L.	13	1
<i>Murraya</i> sp. (incl. <i>koenigii</i>)	12	1
<i>Psidium</i> sp. (<i>guajava</i>)	12	1
<i>Apium graveolens</i> L.	11	1
<i>Persicaria odorata</i> (syn. <i>Polygonum odoratum</i>)	10	1

The infested consignments originate from 43 third countries, with the highest rates of non-compliance for Thailand and Israel (Table 11). The most frequently intercepted *O. basilicum* is imported mainly from Israel while *E. foetidum* arrives mainly from Thailand. Leafy vegetables and herbs present a higher risk of association of *B. tabaci* with the pathway at origin than fruit, because all life stages of the pest usually reside and feed on the underside of leaves. The pest is moderately likely to be associated with the pathway at origin with low uncertainty.

Table 11: Interceptions of *B. tabaci* on fruits and vegetables, including leafy herbs and vegetables for consumption originating from third countries for the period 1993-2011, sorted by country of origin (with more than 10 interceptions)

Country of origin	No of interceptions		Period	
	Absolute	Relative to “Fruits and Vegetables” (%)	From	To
Thailand	647	41	1993	2011
Israel	408	26	1995	2011
Vietnam	84	5	1998	2011
India	75	5	2006	2011
Ghana	62	4	1994	2011
Gambia	44	3	2000	2007
Nigeria	35	2	1996	2011
Cameroon	30	2	1997	2011
Sierra Leone	26	2	2001	2007
Congo	23	1	1997	2011
Morocco	18	1	1999	2005
Zimbabwe	16	1	2002	2011
Senegal	12	1	1997	2005
Canary Islands	11	1	1997	2011

Viruses are associated with the pathway at origin as most trade concerns countries in which viruses are abundant. Few of the food crop species on which *B. tabaci* is intercepted are susceptible to viruses such as *Manihot* spp. and *Ipomoea batatas*. Those viruses have very narrow host ranges and hence suitable host plants are generally not available for viruses infecting cassava and are only very rarely found for viruses infecting sweet potato. However, fruits from virus-infected plants also carry infectious viruses, and cucurbit fruits from infected crops as well as tomato fruits, especially those sold in vines (calyx, peduncle attached) can also present a pathway of entry (Delatte et al., 2003).

3.2.3.2. Probability of survival of the pathogens during transport or storage

The probability of survival during transport and storage depends on the duration of transport but can be generally considered as high. The most relevant life stages for this pathway are the pre-adult stages of the insects, which could be attached to any remaining leaves on fruits or leaves of leafy vegetables, e.g. basil. The fourth nymphal instar is able to survive at low temperatures for days (Bosco and Caciagli, 1998). The second stage of this last instar does not feed (Byrne and Bellows, 1991; Gelman et al., 2002), is resistant to desiccation and can remain viable even on dry foliage (Caciagli, 2007). Thus, *B. tabaci* on foliage of herbal plants is likely to survive during transport or storage with low uncertainty (see also Section 3.2.2.2).

3.2.3.3. Probability of pest surviving the existing management procedures

Leafy vegetables which are hosts of *B. tabaci* are subject to special requirements and should be free of the pest prior to export. Fruits, however, are not regulated and there is a possibility that individuals remain on any leaves that were not removed (e.g. on tomatoes on the vine). Still, regular chemical treatment against other insect pests is likely to reduce the incidence of *B. tabaci*. Other procedures such as washing and removal of the leaves would additionally limit the populations of this pest. The probability of *B. tabaci* surviving the existing management procedures regarding fruits, vegetables and herbs is moderately likely with low uncertainty.

As far as viruses are concerned, CVs will persist with living adult insects that survive, albeit at low rates. Non-circulative viruses likely get lost during probing.

3.2.3.4. Probability of transfer of the pest to a suitable host

For this pathway, the probability of transfer of *B. tabaci* to a suitable host is unlikely for fruits and vegetables because of the cold chain conditions and the fact that pathways generally do not overlap. A risk of transfer of the pest may exist when fruits and foliage are discarded. Late fourth instars of *B. tabaci* attached to discarded foliage surviving cool conditions of transportation can emerge to infest suitable host plants growing in the vicinity of the site of disposal.

The probability that virus-infected fruits would be source of infection for *B. tabaci-transmitted viruses* is very unlikely. However, in regions where *B. tabaci* is established, disposal of fruits and peel from imported cucurbit, melon and courgette, as well as tomato fruits, may present a source of viruses that are transmitted by *B. tabaci* present in the environment.

Considering the lifespan of leafy herbs and especially those species that are marketed as potted plants, the chance for *B. tabaci* life stages to develop and to find suitable hosts is much higher, hence the risk of entry of *B. tabaci* with those leafy vegetables and herbs would increase and the rating is considered as moderately likely.

3.2.4. Results of the probabilistic model on entry

3.2.4.1. Probability of arrival in Europe of *B. tabaci* and viruses

B. tabaci

The frequency of arrival was estimated by grouping into frequency classes. The highest probability of arriving *B. tabaci* (value 0.8) is in the very low class [0, 0.001]. In the low class [0.001, 0.01] the probability is 0.18. In the classes [0.01, 0.05] and [0.05, 0.2] the probability is almost negligible assuming values of 0.016 and 0.004 respectively (Appendix E). The probability of the very high class [0.2, 1] is 0 (Appendix E).

Considering the trade of plant materials—planting, cut flowers, fruits, etc.—the expected frequency of an infested unit arriving in Europe is 2.4/1 000. According to data from EUROSTAT used for the trade volume, a unit is expressed in kilograms of fresh weight.

The probability that the newly arrived *B. tabaci* is a new species for Europe is 0.022, so only 2 % of arriving *B. tabaci* are belonging to species new for Europe. Therefore, 98 % of all *B. tabaci* entering belong to species already present in Europe. In terms of expected frequency it corresponds to 0.048 infested units per 1 000.

Viruses

The probability of entry of a new CV with *B. tabaci* is mainly concentrated in the very low class (probability = 0.53), and progressively decreases in the subsequent classes: 0.28 in the low class; 0.15 in the medium class; and 0.04 in the high class. The very high class has a probability 0. The probability of entry of a new CV with plant material is almost one for the very low class. A very small probability was obtained for medium and high classes (0.0012 and 0.0048, respectively).

The expected frequency of *B. tabaci* infected by CVs arriving in Europe is 7.2 individuals over 1 000, while the expected frequency of plant material infected by new CVs arriving in Europe is 1.1 units (kilograms fresh weight) over 1 000.

For NVs, the results are close to those of CVs. The highest probability of entry of a new NV with *B. tabaci* is in the very low class (0.61) and is 0.3 for the low class, 0.09 for the medium class and zero for higher classes. The probability distribution of entry of a new NV with plant material is the same as in the CV case.

The expected frequency of *B. tabaci* infected by NVs arriving in Europe is 4.7 individuals over 1 000, while the expected frequency of plant material infected by new NVs arriving in Europe is 1.1 units (kilograms fresh weight) over 1 000 as in the CV case.

3.2.4.2. Results per category of commodity

The results obtained by the probabilistic model for entry of *B. tabaci* (Table 12) and viruses (Table 13) are presented and discussed considering the expected frequencies. Furthermore, the standard deviation of the distribution of probability of arrival is calculated. The interval [0, 1] is partitioned in five wide classes (see Appendix E). The large distance between representative points of the different classes produces large standard deviations. A small value for the standard deviation denotes that the probability is mainly concentrated in one class. When the standard deviation is zero the probability is concentrated in only one class. For the distribution of probabilities, refer to Appendix E.

Table 12: Results of the probabilistic model for entry of *B. tabaci*

Category of commodity	Expected <i>B. tabaci</i> infestation level	Standard deviation	Percentage of <i>B. tabaci</i> belonging to new species
Plants for planting	97/1 000	43/1 000	1.5
Cut flowers and branches with foliage	23/1 000	11/1 000	1.8
Fruits and vegetables	1.7/1 000	3.6/1 000	2.2

The expected infestation level of *B. tabaci* is higher in plants for planting (frequencies of 97 units of trade over 1 000 are expected to be infested by *B. tabaci*) than in cut flowers and branches with foliage (23/1 000). The first infestation level can be classified as high and the second as medium. The frequency of *B. tabaci* found on fruits and vegetables however is low (1.7/1 000). The frequency of *B. tabaci* being a new species to Europe is estimated as 1.5 %, 1.8 % and 2.2 % of all arriving *B. tabaci* on plants for planting, cut flowers and fruits and vegetables, respectively.

It is worth noting that the expected number of infested units arriving in Europe, when all commodities are taken together is only 2.4/1 000, a value only slightly higher than the estimated value for fruits, vegetables and herbs. This is because the trade volume of the latter category is very high compared with the volumes of the other two categories: more than 160 times the trade volume of plants for planting and more than 220 times the trade volume of cut flowers. This results in a bias towards the category fruits and vegetables.

For an estimation of the frequencies of viruses arriving with *B. tabaci* and with plant materials, CVs and NVs were considered separately (Table 13). Ornamental plant species are generally not considered susceptible to *B. tabaci*-transmitted viruses, hence virus occurrence on those plants is estimated to be low (9.6/1 000, and because viruses can enter with viruliferous *B. tabaci* on plants intended for planting, this frequency is considered to be medium (25/1 000).

The highest frequencies of arrival of NVs again would be with *B. tabaci* transported on plants for planting (3.7/1 000) and with infected plants for planting (12/1 000).

Table 13: Results of the probabilistic model for entry of circulative (CV) and non-circulative (NV) viruses. The model considers different carriers (*B. tabaci* and infested plant materials) and commodities (plants for planting, cut flowers and fruits and vegetables).

Type of virus	Carrier	Category of commodity	Expected virus prevalence	Standard deviation
CV	<i>B. tabaci</i>	Plants for planting	25/1 000	10/1 000
		Cut flowers	1.3/1 000	1.8/1 000
		Fruits and vegetables	0.5/1 000	1.5/1 000
	Plant material	Plants for planting	9.6/1 000	11/1 000
		Cut flowers	0.5/1 000	0.000.2/1 000
		Fruits and vegetables	0.5/1 000	0
NV	<i>B. tabaci</i>	Plants for planting	3.7/1 000	2.4/1 000
		Cut flowers	0.5/1 000	0
		Fruits and vegetables	0.5/1 000	0
	Plant material	Plants for planting	12/1 000	12/1 000
		Cut flowers	0.5/1 000	0
		Fruits and vegetables	0.5/1 000	0

3.2.5. Conclusions on probability of entry

For entry of *B. tabaci* and the viruses it transmits, five pathways have been identified, and the most relevant one is the plants for planting pathway. Plants not intended for planting (cut flowers and branches with foliage) and the pathway represented by fruits and vegetables were also considered, while entry of *B. tabaci* through human-associated means not involving plants (e.g. on vehicles or clothes) and entry of insects by natural means (e.g. with wind or active flight) were considered negligible pathways and not assessed in this opinion.

Viruses can enter with infected plant material and with insects carrying the viruses (viruliferous insects). Transmission modes of *B. tabaci*-transmitted viruses are substantially different and have a strong influence on the probability of entry. Therefore, viruses were grouped into CVs (begomoviruses) and NVs (all other viruses); these two groups are considered separately in the opinion.

The evaluation of entry of pest and viruses was supported with a probabilistic model that combined expert assessment on the presumed risk of entry from the major world areas with trade volumes of commodities related to the three pathways.

Pathway 1. Plants for planting

- Entry of *B. tabaci* can be expected from all world areas where populations of this insect are established, because *B. tabaci* not only is a polyphagous pest infesting a wide range of plant species (host plants) but also can be carried along on non-hosts, that is with plants on which the insect is only visiting or probing (non-host plants).

- The probability of entry of *B. tabaci* into the EU with the plants for planting pathway is rated as likely, because of the frequent association of insects with the pathway at origin and based on the number of interception records despite strict phytosanitary requirements for places of production of plants for planting. Although the fraction of intercepted consignments relative to the total number of consignments imported in the EU is low, the high trade volumes justify this rating.
- The major volume of trade of this pathway mainly concerns ornamental plants. The specific ornamental plant species that are imported via this pathway are non-host plants for *B. tabaci* -transmitted viruses. Entry of CVs can occur with viruliferous *B. tabaci* insects and with infected plants while NVs can enter only with infected host plants, because of their limited persistence in their vector. Entry of viruses with viruliferous *B. tabaci* or with infected crop plants is considered as moderately likely.

Pathway 2. Cut flowers and branches with foliage

- The probability of entry of *B. tabaci* into the EU with the pathway of cut flowers and branches with foliage is considered as moderately likely because eggs and nymphal stages of the pest can survive transport. Short storage periods and the limited vase life of cut flowers reduce the probability of transfer of insects to a suitable host plant. Although the most important cut flower species require phytosanitary inspection and a phytosanitary certificate for import, interceptions still occurs and the high volume of trade justifies this rating.
- Entry of CVs is bound to viruliferous *B. tabaci* adults. Because survival during transport and storage of adult insects is unlikely, the probability that viruses enter via this pathway is considered unlikely. The probability that NVs associated with *B. tabaci* enter into the EU with cut flowers is rated as very unlikely as the ornamentals of concern are non-host plants for these viruses.

Pathway 3. Fruits and vegetables including leafy herbs for consumption

- The probability of entry of *B. tabaci* into the EU with the pathway fruits and vegetables is estimated as unlikely. These commodities intended for consumption are unlikely to present a pathway because of the pathway characteristics (cold chain) and the low probability of transfer to a suitable host after arrival in the EU. This is despite the numbers of specimens intercepted on commodities entering the EU. Because leafy herbs imported alive as potted plants can have a prolonged vase life, a higher risk is associated with these cases and thus the probability of entry of *B. tabaci* would be moderately likely.
- Insects may enter the RA area on vegetables, leafy herbs (specific regulations apply only for *Ocimum* spp. and *Apium* spp.) and on fruits with remaining leaves (e.g. tomato vines).
- Virus entry with *B. tabaci* on fruits, vegetables and leafy herbs is considered very unlikely, because many species used as leafy vegetables and herbs (basil) are not susceptible to *B. tabaci* -transmitted viruses. There also is a very low probability that transfer from virus-infected fruits to suitable host plants would occur. Notwithstanding this, in regions where *B. tabaci* is established outdoors; discarded fruits or peels can be sources of infection and pathways of virus entry.

Information on *B. tabaci* interceptions shows that control measures and phytosanitary requirements in the area of production and inspections have limitations to preventing insects from entry. The limited efficacy of inspections at entry and the high volumes of trade attribute a medium uncertainty to the evaluation of the risk of entry of *B. tabaci*. There is further uncertainty about aquatic plants entering the EU, on which *B. tabaci* is frequently intercepted. The lack of information on their final use in the EU contributes to uncertainty. Because of dual use, some commodities can be assigned to either pathway 2 or pathway 3. For some species, e.g. *Eryngium* sp. and *Limnophila aromatica*, high rates of interception were observed on cut flowers in the past, but presently these generate interception reports almost exclusively as vegetables and fruit for consumption. Because cut flowers and branches with foliage are subject to more stringent import requirements and fruits and vegetables for consumption

are largely not regulated, such changes in the commodity class further contribute to uncertainties on the ratings of the entry pathways for *B. tabaci*.

For viruses transmitted by *B. tabaci* there is uncertainty whether newly introduced ornamental plant species including aquatic plants can be new host plants for hitherto unknown viruses. However, the uncertainties concerning new viruses entering into the EU with any of the pathways can be rated as low.

The application of measures for import consignments that pose a risk seems to be most effective to reduce the probability of entry with all major entry pathways for *B. tabaci*. However, interception reports indicate the limitations of the measures.

Rating <i>B. tabaci</i>	Justification
<p>Plants for planting</p> <p>Likely</p>	<ul style="list-style-type: none"> • <i>B. tabaci</i> is frequently associated with the pathway at origin, especially in countries where the insect is established and present throughout the year. However, as a result of pest management measures commonly implemented, <i>B. tabaci</i> infestations at the place of production are estimated to be between low and medium (in the model, between 0.1 % and 5 % of infested plants are estimated depending on the region of origin (see Appendix E). • A high number of interceptions is reported but inspections might not cover the entirety of whiteflies present and thus are not fully reliable • The volumes of movement along all three pathways are high and the commodities are distributed throughout the whole RA area. • <i>B. tabaci</i> is likely to survive transport and storage. The expected survival rate during transport is estimated by the model as 8.7 % (Appendix E). • The probability that <i>B. tabaci</i> also survives management procedures is estimated as high (10 %, see Appendix E). This high value is particularly because, with plants for planting, a high probability of transfer to suitable hosts exists, taking the high polyphagy of <i>B. tabaci</i> into account. • The current regulations do not specify the methods to be used in surveys to confirm pest freedom, official inspections and treatment to eliminate <i>B. tabaci</i> when present on plants for planting prior to export from third countries to the EU.
<p>Cut flowers and branches with foliage</p> <p>Moderately likely</p>	<ul style="list-style-type: none"> • Similar to the plants for planting pathway, whiteflies are frequently associated with the pathway at origin, especially in countries where the insect is established and present throughout the year. Because of cold transport and storage conditions, mostly eggs and nymphal stages will survive during transport and storage on infested cut flowers. The high volume of trade increases the likelihood that transfer to a suitable host occurs. • Branches with foliage are not regulated. In particular, branches with berries of <i>Hypericum</i> are not subject to regulation.

<p>Non-circulative viruses</p> <p>Moderately likely for plants for planting</p>	<ul style="list-style-type: none"> • The probability of entry for NVs is rated as moderately likely, considering the entry of infected susceptible crop plants but also accounting for the very large volume of trade of non-susceptible ornamental plants. • NVs are frequently associated with tomato, cucurbit and legume crops in countries where <i>B. tabaci</i> is established, thus presenting a pathway of entry.
<p>Very unlikely for cut flowers</p>	<ul style="list-style-type: none"> • Ornamental plant species used for planting, and species generally used for cut flower production, as well as the many aquatic plant species, are not known to be susceptible to the viruses concerned. • NVs are generally lost in <i>B. tabaci</i> adults surviving during transport and storage on these plant species because infectivity is generally lost within a short time on non-infected plants. • Leafy herb species are generally not considered host plants for <i>B. tabaci</i> (reports for ToCV exist). Thus, <i>B. tabaci</i> adults on leafy herbs are very unlikely to transmit NVs.
<p>Very unlikely for vegetable herbs and fruits and vegetables</p>	<ul style="list-style-type: none"> • While fruits of tomato and cucurbits can originate from infected plants and <i>B. tabaci</i> can remain on produce, because of cold storage, it is very unlikely that NVs arriving with fruits and vegetables can be transferred to suitable host plants. • In regions where <i>B. tabaci</i> is established, discarded fruits and pees from infested plants can however present a source of infection, which would however be a very rare event.

3.2.6. Uncertainties on the probability of entry

<p>Rating <i>B. tabaci</i></p>	<p>Justification</p>
<p>Medium</p>	<ul style="list-style-type: none"> • The main uncertainties for <i>B. tabaci</i> relate to the pathway of plants for planting and specifically to the level of risk represented by aquatic plants as it is unclear what methods for cultivation are used before and after entry into the PRA area and whether they are hosts for <i>B. tabaci</i>. Another uncertainty stems from the fact that <i>B. tabaci</i> is highly polyphagous and it is likely that new hosts will be confirmed in the future. Also, there is insufficient information on the exact species of ornamentals in the trade in cut flowers. • The analysis of the interception data shows that, for some species, there is a shift in the commodity class generating reports. Some plants fall into several categories and there is uncertainty regarding the intended use of such imports.

Rating viruses	Justification
Low	<ul style="list-style-type: none"> Based on the model results and expert opinion, the uncertainty regarding <i>B. tabaci</i>-transmitted viruses surviving transport and storage is considered low, because virus infections persist as long as plants continue to live, which is also true for parts thereof, cuttings and tubers. Uncertainty on the persistence of viruses in <i>B. tabaci</i> are low, as <i>B. tabaci</i> will remain viruliferous for CVs while NVs will be lost after a short time. The probability that <i>B. tabaci</i>-transmitted viruses arrive is estimated in the model with medium to high frequency with low standard deviation (Appendix E). Based on expert opinion on the likelihood of potential movement along the pathways the uncertainty is rated to be low. The main uncertainties relate to the level of risk presented by the large number of aquatic plant species, new ornamental species for planting and cut flower use because of their unclear status as a host for viruses. Uncertainty also exist on the importance of viruliferous <i>B. tabaci</i> on cut flowers and leafy herbs to act as vectors for circulatively transmitted viruses

3.3. Probability of establishment

3.3.1. Reports of *B. tabaci* and the viruses it transmits in the RA area

As indicated in the pest characterisation section, *B. tabaci* is reported (few occurrences to widespread) from most of the EU 27 countries (see Appendix C). In these countries, *B. tabaci* is mainly found under protected environments (greenhouses, tunnels). It can be found in open fields throughout the year in several countries from the Mediterranean area (Cyprus, Greece, Italy, southern France, some areas in Spain and Portugal) (see Figure 3). Only a few areas, mainly from northern Europe are free of *B. tabaci*. Some of these countries (United Kingdom, Finland, Ireland and Sweden) and some areas of Portugal, have a PZ status.

Even though absent or rarely observed in some countries, *B. tabaci* specimens are regularly intercepted in EU countries including the PZ, e.g. the United Kingdom and Finland (Cuthbertson et al., 2011; EPPO, 2012a) in plant materials circulating within the RA or coming from non-European countries (see Table 14).

B. tabaci-transmitted viruses can establish wherever *B. tabaci* is established in nature and perennial, virus-susceptible hosts are present to act as virus reservoirs. While *B. tabaci* can infest many plants, the viruses transmitted by this insect are associated with few main hosts, e.g. tomato, pepper, beans and cucurbits and a small number of alternative hosts, e.g. *Solanum nigrum* for TYLCV, that act as virus reservoirs. In areas where susceptible crops are grown under open field conditions in Europe, *B. tabaci*-transmitted begomoviruses causing TYLCV are found in tomato (Papayiannis et al., 2011). When introduced into a greenhouse with susceptible crops, the virus can establish as reported in tomato in the Netherlands and it can cause an outbreak but it will not establish outdoors due to adverse climatic conditions and thus can be eradicated (Netherlands Plant Protection Service, online).

The number of viruses reported in the RA area concerns mostly viruses of crops and is fairly stable for circulatively transmitted begomoviruses but highly dynamic for NVs. There are newly emerging viruses, such as the torradoviruses, but also disappearing ones, such as BnYDV, indicating that entry and establishment processes are probably still ongoing.

3.3.2. Availability of suitable host plants in the risk assessment area

As stated in Section 3.1.4 and shown in the list of host plants in Appendix B, *B. tabaci* is highly polyphagous and the range of its host plants is probably underestimated. A large number of hosts are species of economic importance (tomato, cucurbits, aubergine, poinsettia,) and grown in protected environments or in open fields. Many wild plants are host plants for *B. tabaci* and sustain *B. tabaci* populations in crop-free periods and during overwintering. They represent the continuum of the year-round *B. tabaci* reservoir. A high number of host plants, crops and wild plants are present in Europe, outdoors in open fields and in protected environments.

For viruses, the range of susceptible hosts is restricted to only a few crops with a small number of alternative hosts to sustain their survival in nature. The year-round presence of susceptible crops, as is the case in greenhouse cultivation, however, provides suitable host plants to maintain virus infections too.

As tomato and cucurbits, major hosts for *B. tabaci* and the associated viruses, are widely cultivated in the EU, the Panel considers that the entire RA area provides suitable environmental conditions for *B. tabaci* and the viruses it transmits (Appendix B).

3.3.3. Suitability of the environment

3.3.3.1. Suitability of the climate

As described in Section 3.1.1, all biological features of *B. tabaci* are strongly influenced by temperature. The lower thermal threshold is around 10 °C and the upper thermal threshold is around 30 °C with populations existing that can even survive temperatures higher than 32–33 °C (Muñiz and Nombela, 2001; Bonato et al., 2007). As a result, several areas in Europe have suitable climatic conditions for survival of *B. tabaci*. From only a few individuals, the high reproductive potential and multivoltinism of *B. tabaci* can result in strong population growth in greenhouses and outdoors when temperatures favourable for *B. tabaci* are prevailing (Arnó et al., 2009; Appendix B). Thus, in the RA area, the probability of establishment in nature, open fields and under protected conditions is likely, particularly in the coastal Mediterranean regions of Europe. In northern Europe, suitable environments are provided only in greenhouses and the probability of establishment outdoors is considered as very unlikely as indicated by the findings of *B. tabaci* in open fields (see Figure 4). Although individuals may escape from greenhouses in northern areas of the EU to establish temporary populations existing for one or two generation cycles in open fields, such transient populations cannot establish permanently because the climatic conditions are favourable only for a short time.

The probability of establishment of arriving *B. tabaci* in the PZs needs to be evaluated for two European climatic zones separately: the PZ zone comprising northern European countries and regions of Portugal with PZ status that fall within the climatic ranges in which *B. tabaci* could establish (i.e. central and northern parts of Portugal, Madeira and the Azores archipelago).

For the northern PZ zones, the suitable climatic conditions are present only in greenhouses, so the probability of establishment outdoors is very unlikely. For the PZ regions in Portugal, climate and host plant conditions are similar to those found in the Mediterranean area, so suitable conditions are found in greenhouses and the field at least for part of the year, making the probability of establishment likely.

Viruses are adapted to their hosts and, within the range suitable for plant growth, increasing temperatures increase replication rates and systemic movement in the host. For viruses adapted to tropical and subtropical plants (tomato, cucurbits) those are adapted to high temperatures while low temperatures lead to delayed infections or even break-off. Whitefly-transmitted viruses in general require high temperatures (> 26 °C) for optimal plant infection and development of disease. Below 22 °C inoculations are not certain to result in virus infections. These temperature ranges lie well

between the conditions used for production of cucurbits and tomato. Since virus establishment is also bound to *B. tabaci* the environment suitable for viruses, insects and host plants is congruent. This is illustrated by the expansion of *B. tabaci* in the Mediterranean basin linked to the westward spread of TYLCD (Moriones and Navas-Castillo, 2000).

3.3.3.2. Dimensions of the ecological niche

Establishment of a newly arriving *B. tabaci* may be driven by the presence or absence of competitors, the nature of competitors (i.e. other *B. tabaci* species or further phytophagous insects sharing the same resources), the presence of natural enemies and the potential of the new *B. tabaci* species to establish or to invade and displace endemic/local populations.

Newly arriving *B. tabaci* populations are likely to encounter other plant pests (established *B. tabaci* species, other whiteflies such as *T. vaporariorum*, aphids and thrips) which may compete for similar space and resources. In Europe, the most predominant and well-established *B. tabaci* species are Med and in some regions MEAM1. As proven by their global occurrence and the worldwide invasion history of *B. tabaci*, these species are particularly invasive and competitive, and their introduction probably leads to displacement of resident *B. tabaci* species (Pascual and Callejas, 2004; Liu et al., 2007; Crowder et al., 2010a, b; De Barro and Bourne, 2010; De Barro et al., 2011; see also Section 3.1.11).

Establishment after entry of other *B. tabaci* will therefore depend on the presence or absence of MEAM1 and/or Med *B. tabaci* in a particular environment (occupied niche versus empty niche). When Med and MEAM1 originating from third countries enter into Europe, they integrate into existing populations provided that they are conspecific and belong to either of the species. Invasiveness is proven only for *B. tabaci* MEAM1 and Med; thus when other species (i.e. Asia II species) not present in Europe arrive, their establishment will mainly depend on their potential to evade competition with existing MEAM1 and Med, which are highly successful on crops such as tomato or cucurbits, and to occupy niches as indicated/illustrated by populations of the T- and the SSA2 *B. tabaci* species in Italy and Spain, respectively.

It is also likely that introduced *B. tabaci* have to face natural enemies either present in the environment or released because of biological control programmes. The pressure exerted by predators, parasitoids and other organisms may limit but not prevent new *B. tabaci* from establishing.

The plasticity of virus genomes makes them adapt to host plants and situations in which host plants are grown. The enormous genome diversity of begomoviruses transmitted by *B. tabaci* is illustrated by the large number of virus species causing TYLCD. In Europe, two of the four TYLCD viruses result from recombination events between viruses present in mixed infections. Thus, virus diversity is constantly generated that may lead to new virus species but more serious or mild disease phenotypes or adaptation to new hosts. More serious disease symptoms of a more severe virus must not necessarily be a selective advantage. TYLCV is a virus that unlike other tomato-infecting begomoviruses is most widespread around the world. Other viruses can result in more serious diseases, but TYLCV can use, for example, beans as alternative hosts while others are strictly confined to tomato crops.

3.3.4. Cropping practices and control measures

Since the 1980s, severe population outbreaks of *B. tabaci* and subsequent virus epidemics have been related to intensive monoculture cropping systems and some cropping practices involving irrigation, use of fertilisers, and the presence of several cycles of crop production per year (i.e. tomato production in Almeria, Spain (Arnó et al., 2009)), even year-round (i.e. tomato production in Roussillon, France (Arnó et al., 2009)), with genetically uniform crop varieties (Brown, 2007): in short: disturbed agroecosystems. Year-round production has eliminated or shortened host-free periods, facilitating population increase (Brown, 2007). The use of protected and heated crop production systems have

created “artificial” agro-ecosystems which has allowed the establishment of new *B. tabaci* in areas and periods where natural climatic conditions and/or resources would normally not permit development.

During the past 40 years, cropping practices have created suitable conditions for *B. tabaci* establishment in many areas in Europe. However, recent pest management methods have been developed, including cultural methods, which are effective in limiting, but rarely avoiding, the establishment of *B. tabaci* (see Section 4).

The production systems and the climate of regions with intensive crop production, such as major production areas of tomato in the EU (Italy, Spain, Greece, Portugal, southern France (Arnó et al., 2009)) could be particularly sensitive for new establishments.

Cultural practices are not limiting the establishment of *B. tabaci*-transmitted viruses. Most tomato cultivars with resistance to TYLCV are rather tolerant to the disease but support virus replication. The use of genetically homogeneous crops and vegetative propagation, through grafting of improved cultivars on tomato rootstock, rather favours virus establishment.

3.3.5. Other characteristics of the pest affecting the probability of establishment

3.3.5.1. Species adaptation

Genetic diversity is the main basis for species adaptation. The two highly invasive *B. tabaci* MEAM1 and Med, and in particular the Med species, have been shown to include numerous distinct genetic entities: some of them being invasive and widespread worldwide, and others endemic in non-European areas (Dalmon et al., 2008; Tsagkarakou et al., 2007, 2012; BemisiaRisk, 2010; Gueguen et al., 2010; De Barro and Ahmed, 2011). The adaptation potential of these two species is illustrated by their present distribution across all the continents and over a large range of climatic conditions, their large host plant range which is still expanding, and the ability to develop resistance to different groups of insecticides.

Adaptation is a feature common to all viruses and on particular begomoviruses can adapt to diverse environments and host plants.

3.3.5.2. Other biological traits

While the minimum population size needed for establishment remains unknown, the biological characteristics (e.g. developmental and survival rates, fecundity, adult longevity, polyphagy) and the large ecological niche occupied by MEAM1 and Med, together with their invasion history often associated to bottlenecks, are in favour of successful establishment of new populations from a small number of founders. A minimum inoculum is also needed to establish virus infections. This is already provided by a single whitefly acquiring virus from an infected source plant. The higher the abundance of whiteflies the more efficient is virus infection in plants.

3.3.6. Area of potential establishment

Suitable conditions—availability of a large range of host plant species and climatic conditions—to allow several generations in greenhouses during a growing season are widespread in the RA area. The pest can also survive and reproduce outdoors in part of the Mediterranean area.

For the two most invasive species worldwide, a limitation of establishment in the RA area due to competition with other congeneric species and the presence of natural enemies is not expected, even though these can reduce the population density of *B. tabaci*.

The wide availability of host plants would support establishment in the RA area; however, unfavourable temperatures limit the distribution of *B. tabaci*. The area of potential establishment under

current climatic conditions and under a scenario of climate change was estimated using a probabilistic model developed for this opinion (see Sections 3.3.6.1 and 3.4.4, respectively).

B. tabaci-transmitted viruses have a similar requirement for climatic conditions and host plant availability as their vectors. Susceptible hosts for viruses can be host plants for *B. tabaci* or plants on which *B. tabaci* probes only for a time sufficient to transmit virus and to introduce infections. Thus, susceptible host plants for viruses do not necessarily have to be host plants on which *B. tabaci* can fulfil an entire life cycle. Virus species have a defined range of host plant species and the availability of those host plants is decisive for their establishment. The broader the range of susceptible species, e.g. wild solanaceous hosts as reservoirs for TYLCV, the more likely the chance of establishment. However, from a practical point of view, the area of potential establishment for the viruses is identical to that for their vector.

3.3.7. Results of the probabilistic model on establishment

3.3.7.1. *Bemisia tabaci* establishment

A numerical simulation of the population dynamics of *B. tabaci* was performed for each node of the grid (see Appendix E for description of the model). The index of population pressure related to average population abundance is given in a map for the reference conditions (climatic data, and a single inoculum; see Figure 9). The model output has been validated considering all the available information on the distribution of open field records of *B. tabaci*. The simulated data of *B. tabaci* distribution well approximate the presence of *B. tabaci* in the open field. Some discrepancies may result from the spatial resolution in the simulation, because it does not always consider points along the Mediterranean coast, which in many regions represents the only suitable environment for *B. tabaci* (for example, the Liguria Region in Italy). The comparison between field records and simulated data also assists in defining the value of the threshold of the population abundance under which the presence of *B. tabaci* is very unlikely or can be excluded. This threshold is set equal to one adult per plant.

The results of the simulations can be used to define the area of potential establishment for *B. tabaci*. In conclusion, the area of potential establishment corresponds to the area for which the index of population pressure is greater than zero (see Figure 9). *B. tabaci* establishment outside the area defined in Figure 9 is not expected, nor will *B. tabaci* colonise separated areas or expand northwards. This is because of the influence of lower temperatures on development, fecundity and mortality. Hence, countries in northern Europe (e.g. Ireland, UK, Sweden, Norway and Finland) are considered outside the area of potential establishment. For other northern European countries (such as Germany, the Netherlands, Poland) the possibility of establishment in open fields can also be excluded or considered as very unlikely.

The competitive capacities of different *B. tabaci* species have been compared in recent publications (De Barro and Hart, 2000; Pascual and Callejas, 2004; Liu et al., 2007; Crowder et al., 2010a; De Barro and Bourne, 2010; see Annex B). There is no evidence that other *B. tabaci* species have characteristics to outcompete the existing Med and MEAM1 populations at their present locations.

It can also be assumed that all *B. tabaci* species have similar temperature requirements and hence *B. tabaci* species new to Europe are unlikely to invade locations outside areas in which *B. tabaci* MEAM1 and Med have established. Based on these results, we expect new *B. tabaci* species not to invade and establish in new areas but rather to colonise marginal habitats, e.g. outside disturbed agricultural ecosystems within the area marked by the temperature limits. The possible role of climate change on the probability of spread of *B. tabaci* and its viruses is considered.

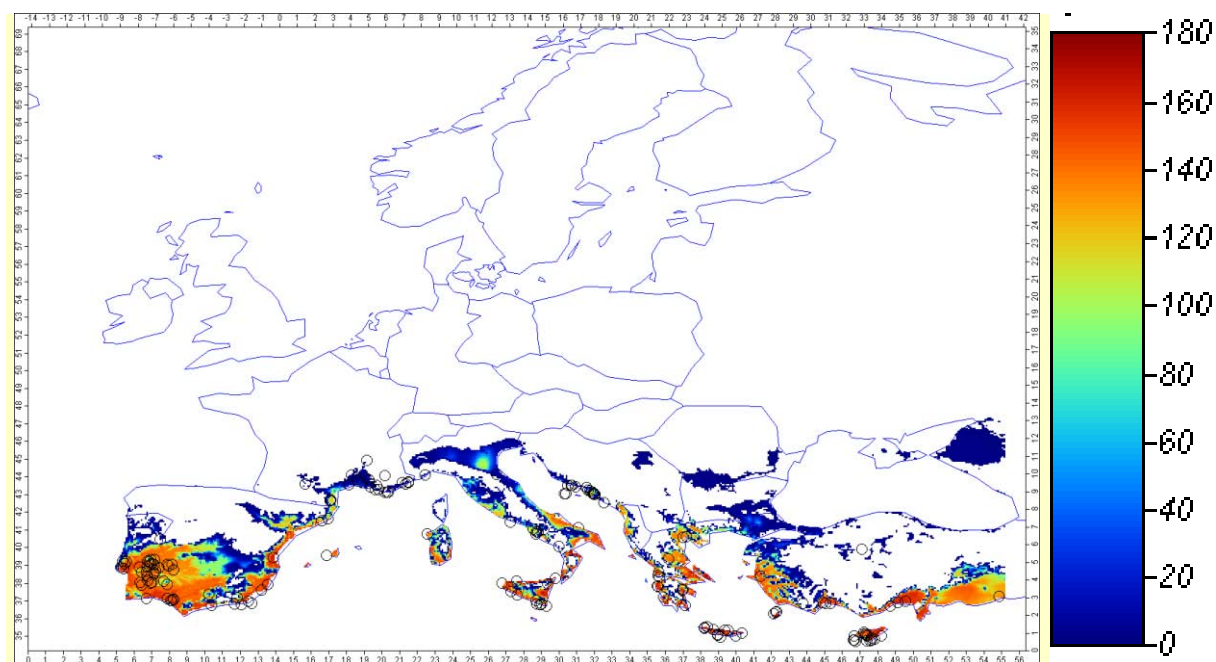


Figure 9: Distribution of *B. tabaci* in Europe based on population dynamics model simulation compared with open field records (empty circles). The colour represents the level of population abundance expressed in terms of the index *BP* (see Section 2.1.3.4.)

3.3.7.2. Virus establishment

Virus distribution is bound to the presence of *B. tabaci* and the availability of host plants. The contribution of *B. tabaci* population dynamics to virus establishment was investigated by considering that both wild and cultured host plants are available. The spatial distribution of the probability of virus establishment in the current climatic situation and for a climatic scenario (+2 °C) is reported in Appendix E, Figures E.4 and E.5). It shows that long-term establishment of viruses is not possible outside the areas where *B. tabaci* can potentially establish. The probability of establishment is significantly higher than zero for coastal Mediterranean regions of Europe, while the only regions further inland that are suitable for virus establishment are in western Spain and southern Portugal.

3.3.8. Conclusions on probability of establishment

B. tabaci species MEAM1 and Med are established in many parts of the RA area. Since there are many host plant species available for these polyphagous pests, outdoor establishment is limited only by climatic conditions. The assessment of *B. tabaci* establishment is supported by the results of a population dynamics model that was developed with biodemographic temperature-dependent functions estimated for *B. tabaci* in which climatic data were used to predict the area of potential establishment of the insect and the viruses it transmits in Europe.

- Assuming similar climatic requirements for all *B. tabaci* species, outdoor establishment of *B. tabaci*, including those species entering from outside into the RA area, is considered as likely within the areas where *B. tabaci* already is present. Similarly, the climatic conditions for crop production in greenhouses favour *B. tabaci* population development and, as proven by records of outbreaks in greenhouses, once is *B. tabaci* introduced it is likely to establish.
- In crops such as tomato or cucurbits, Med and MEAM1 are well adapted to the intensive production conditions, and newly invading *B. tabaci* species would probably be less competitive in those crops but may establish on other plant species. Because *B. tabaci* Med and MEAM1 are highly invasive species and present around the world, it is likely that insects entering into the EU are MEAM1 and Med, and those would merge with existing populations of the same species.

In Europe, several *B. tabaci*-transmitted viruses are present in regions where the insect is established outdoors. Those causing TYLCD are considered among the most serious plant viruses in crops.

- Because of the availability of suitable host plants and the presence of efficient vectors, viruses transmitted by *B. tabaci* are likely to establish. This assessment concerns viruses infecting tomato and cucurbit crops which are available almost throughout the year in the production areas of the Mediterranean regions (greenhouses and outdoors) and in the greenhouses of northern EU countries.
- New diseases from recently emerging (novel) *B. tabaci*-transmitted viruses mostly recorded on cucurbits and on tomato provide evidence for newly introduced pathogens and indicate ongoing processes of establishment.
- As far as establishment of other *B. tabaci*-transmitted viruses is concerned, their establishment largely depends on suitable host plants being available in the environment and serving as reservoirs for survival and new plant infections. The availability of alternative host plants is not an important requirement for viruses infecting tomatoes and cucurbits.
- Newly introduced begomoviruses infecting tomato would likely contribute to TYLCD, establish mixed virus infections or compete with existing TYLCV that are highly adapted to tomato.

Uncertainties concerning the assessment of outdoors establishment of *B. tabaci* are rated as low, because, according to the population dynamic model, estimates on the area of supposed establishment and the northern limits of expansion can be well defined. *B. tabaci* -transmitted viruses are established outdoors in several EU MSs. Uncertainties concerning the establishment of *B. tabaci* in greenhouses are also rated as low because of controlled climatic conditions favouring the population development and growth of this insect.

The uncertainty rating for the establishment of newly introduced viruses, however, is considered as medium because of the limited knowledge about factors driving the epidemics of NVs.

Rating <i>B. tabaci</i> and viruses	Justification
Likely	<p>Based on published data and results of model simulations, establishment is globally rated as likely for newly arriving <i>B. tabaci</i> into the RA area and the PZ. This conclusion is based on the following evidence:</p> <ul style="list-style-type: none"> • Suitable climatic conditions can be found in greenhouses practically all the year round, representing a possible refuge. Outdoors, suitable climatic conditions exist only in coastal Mediterranean regions. Model predictions about suitable areas for <i>B. tabaci</i> establishment are similar to the areas where the pest is currently found. • Everywhere in the RA area, suitable host plants are present either in greenhouses or in the field for establishment of <i>B. tabaci</i>. In the Mediterranean region, establishment is increased by the large range of wild host plant species that can play an important role as a year round reservoir. In northern European countries climatic conditions during warm summers permit temporary <i>B. tabaci</i> population development outdoors. However these <i>B. tabaci</i> populations remain transient because of adverse climatic conditions. • The high potential of adaptability of <i>B. tabaci</i> is an important factor facilitating establishment. • Med and MEAM1 from outside Europe are likely to mate with existing populations merging into and establishing. • For non-European new <i>B. tabaci</i> species, the presence of well-established MEAM1 or Med <i>B. tabaci</i> over large areas and the low propagule pressure exerted by new <i>B. tabaci</i> species (i.e. the probability of new arriving <i>B. tabaci</i> to be a new species was estimated at only 2% by the model), lead to the conclusion that the potential of establishment of new <i>B. tabaci</i> species is rated as low. • Several <i>B. tabaci</i>-transmitted viruses are already established in the RA area. New diseases from emerging <i>B. tabaci</i>-transmitted viruses are reported indicating ongoing processes of establishment following entry. • It can be assumed that all viruses have similar climatic and vector requirements hence their establishment is only limited by suitable host plants. Viruses that can infect tomato, pepper and cucurbits widely grown in Europe are likely to establish.
	<p>In the Protected Zone</p> <ul style="list-style-type: none"> • The probability of establishment of <i>B. tabaci</i> in the PZ is very unlikely for the northern PZ because suitable climatic conditions are only present in greenhouses. • For the PZ regions in Portugal, climate and host plant conditions are similar to those found in the Mediterranean area, so suitable conditions are found in greenhouses and the field at least for part of the year, making the probability of establishment likely.

3.3.9. Uncertainties on probability of establishment

Rating	Justification
<p><i>B. tabaci</i> Low</p>	<p>There are uncertainties related to the identity of the <i>B. tabaci</i> species, the data on the current distribution of <i>B. tabaci</i> throughout the EU territory, as well as the efficiency of the control measures in the area of introduction. Still, the uncertainties associated to the estimation of the probability of establishment are low, because:</p> <ul style="list-style-type: none"> • Availability of host plants is not a limiting factor for establishment. • The estimated ratio between new and non-new <i>B. tabaci</i> species arriving to the EU is low. • Intraspecific mating between the local and the arriving <i>B. tabaci</i> (i.e. MEAM1 and Med) and interspecific interactions (competition/ avoidance of competition between new species vs. local species) will be possible. • The possible northern limit for establishment of <i>B. tabaci</i> under field climatic conditions and under scenarios of climate change can be readily estimated. Even if transient populations of <i>B. tabaci</i> would occur outdoors in northern EU areas, they will not affect the northern limit of establishment, because suitable environmental conditions will be present only for a short period of time during warm summers and are restricted in space.
<p>Viruses Medium</p>	<p>The uncertainty associated with establishment of viruses is medium because the success of newly introduced viruses to establish cannot be estimated. In tomato, interaction with existing viruses highly adapted to the crop can lead to synergistic interactions or competition. For NVs the rather infrequently occurring epidemic episodes make the assessment whether establishment is transient (torradoviruses) or set uncertain.</p>

3.4. Probability of spread after establishment

3.4.1. Dispersion by natural means

Only *B. tabaci* adults can have directional and active flights. Whiteflies seldom need to fly more than a few centimetres to a few metres to find suitable host plants. They may cover distances of a few kilometres. *B. tabaci* adults can spread over longer distances by passive transport with wind. Passive long-distance dispersal by wind may result in spread of whitefly to uninfested fields and to wild host plants, to other areas in the same country or to neighbouring countries. However, as far as we know, there is no published information on long-distance dispersal by natural means resulting in infestation of new areas by *B. tabaci*.

Most viruses concerned in this opinion spread in nature exclusively by *B. tabaci*. This is the case for all begomoviruses while for a number of crini- and torradoviruses, other whitefly insects, particularly *T. vaporariorum*, can efficiently transmit TICV and ToCV as well as ToTV. There is no transfer of virus by pollen or seeds. Mechanical transmission by wounding, although possible under experimental conditions for some viruses (e.g. CVYV), is highly unlikely to occur.

3.4.2. Dispersion by human activities

Records of *B. tabaci*, described in Section 3.2 and reported in Annex C, and analysis of the pathways of entry show that long-distance dispersal of *B. tabaci* occurs through intensive global trade in plant commodities as an efficient mean for long-distance transport of eggs, nymphs and adult *B. tabaci* insects. Trade in ornamentals is considered as responsible for the global spread of the two main invasive *B. tabaci* species from their presumed area of origin, the Middle East–Asia Minor region for the MEAM1 species and the Mediterranean basin for the Med species. The global invasion of the whitefly was associated with a global invasion of TYLCV which was vectored by insects infesting ornamentals that were non-host plants for the virus, and tomato plants infected with TYLCV for planting (Lefeuvre et al., 2010; De Barro et al., 2011).

The rapid spread of *B. tabaci* over wide areas thus is a result of human activities. After the first detection of Med in Arizona in 2004, it was detected in 19 US states in 2005, and in 2011 it was found in 23 US states and Mexico, with first reports of Med in Canada and the Bermudas (McKenzie, 2012). During the past six years, this species has spread over thousands of kilometres in the Americas.

The probability of spread of newly arrived and established MEAM1 or Med *B. tabaci* within the RA area where the species are already established is high. It is likely that newly arriving insects will merge with already existing specimens of the same species.

Although spread of *B. tabaci* in Europe concerns almost exclusively MEAM1 and Med, other species can disperse as well. As stated above, the sub-Saharan Africa 2 (SSA2) species first reported in Spain in the 1990s (Banks et al., 1998, in De la Rúa et al., 2006) but was recently also found on soybean in France and on aubergine and *Datura* in Tunisia (BemisiaRisk, 2010). SSA2 species were earlier reported from cassava in Uganda (De la Rúa et al., 2006). While the invasive potential of SSA2 is unclear, this indicates that *B. tabaci* species, probably introduced with particular host plants (SSA2 on *I. indica*), can establish and then spread to particular crops that are not common, thus enlarging their host plant range and area of distribution.

The potential of spread of new *B. tabaci* species is rated as low owing to the presence of well-established MEAM1 or Med *B. tabaci* over large areas and the low expected propagule pressure of new *B. tabaci* species. Also new non-European viruses are also likely to be spread by established MEAM1 and Med populations.

Whitefly vectors remain viruliferous throughout their lifespan for begomoviruses and thus long-distance transport is realised with infected plants but also with *B. tabaci* on non-hosts. NVs are lost on non-host plants after short periods (several hours to a few days), thus would require infected plants for long-distance spread. Thus newly emerging viruses, such as the torradoviruses, and their long distance spread are closely linked to exchange of germplasm and trade of planting materials infected with these viruses.

3.4.3. Dispersal to protected zones

The introduction and spread of *B. tabaci* within the protected zones (PZs; listed in Annex I, Part B of Council Directive 2000/29/EC) is banned. There are special requirements for movement of certain plant commodities into the PZ which are listed in Annex IV, Part B of the same Directive. They relate to plants for planting: *Euphorbia pulcherrima*, *Ficus* spp. and *Hibiscus* spp. General information on trade between EU MSs is reflected by interceptions of *B. tabaci* in PZs in commodities originating from the EU (Table 14).

Table 14: General data on interceptions of *B. tabaci* on plant commodities originating from the RA area for the period 1993 – 2011 (Source: EUROPHYT).

Commodity	Number of interceptions	Relative part (%)
Plants for planting	625	74
Fruit and vegetables	6	1
Cut flowers and branches with foliage	208	25
Total	839	

Data indicate that recurrent entries of *B. tabaci* occur in the PZ countries indicating spread to protected zones. From 1993 to 2011 the number of interceptions of *B. tabaci* on plants for planting originating from EU countries is 625, which represents 74% of all interceptions of the pest on plant commodities (Table 14). The highest percentage of interceptions are reported on ornamental plants for planting (*Euphorbia* spp. (61%) and *Hibiscus* spp. (17 %), most of them originating from The Netherlands (46 %) and Germany (17 %) (Table 15).

Table 15: Interceptions of *B. tabaci* on plants for planting originating from EU countries for the period 1993–2011 (with more than 10 interceptions per plant)

Plant / Country	Belgium	Denmark	France	Germany	Italy	Netherlands	Portugal	Slovakia	Spain	Sweden	United Kingdom	Relative part
<i>Euphorbia pulcherrima</i> (incl. other spp.)	4	16	1	98	18	131	40		9	6	2	61%
<i>Hibiscus</i> sp.(incl. <i>rosa-sinensis</i>)	9	1			8	81	3	1	2			17%
<i>Mandevilla</i> sp.	3				2	20	1		2			4%
<i>Lantana</i> sp. (incl. <i>camara</i>)		1			3		3		1			2%
<i>Ajuga</i> sp. (incl. <i>reptans</i>)						17						2%
Total interceptions / country	19	19	1	106	38	290	54	1	25	7	2	

Twenty per cent of all interceptions of *B. tabaci* from EU countries on plant commodities were recorded for cut flowers and branches with foliage, mainly *Solidago* sp, *Trachelium* sp and *Chrysanthemum* sp. 79 % of all interceptions from the EU countries relate to consignments originating from The Netherlands (Table 16).

For fruits and vegetables, including herbaceous plants for consumption, only two EU countries are reported; The Netherlands with 21 interceptions and Cyprus with six interceptions.

Table 16: Interceptions of *B. tabaci* on cut flowers and branches with foliage originating from EU countries for the period 1993–2011 (with more than 10 interceptions)

Plant Species/Genera	Country of origin					
	Germany	Ireland	Italy	Netherlands	Spain	Relative part
<i>Solidago</i> sp. (incl. <i>S. canadensis</i>)		2		81	23	63%
Unknown plant species				22		11%
<i>Hypericum</i> sp. (incl. <i>H. xylosteifolium</i>)				20		10%
<i>Trachelium</i> sp. (incl. <i>caeruleum</i>)			1	18		11%
<i>Chrysanthemum</i> sp.			2	15	5	9%
Total interceptions / country	2	2	3	172	29	

In very few cases only, *B. tabaci*-transmitted viruses were recorded from interceptions. This is because specific tools have to be applied to detect viruses arriving with *B. tabaci*. When plants showing symptoms, e.g. TYLCV infections in *Lisianthus*, or when outbreaks occur (TYLCV in tomato in the Netherlands), interceptions or eradication following outbreaks are applied (NPPS, online). Because ornamental plants for planting are not host plants for *B. tabaci*-transmitted viruses, *B. tabaci* are only viruliferous for CVs if ornamentals and food crops are cultivated at the same location. Because of the highly specialised cultivation conditions, this case is unlikely.

3.4.4. Model results for *B. tabaci* and virus spread

B. tabaci and viruses spread outdoors within the boundaries set by prevailing climatic conditions suitable for the insects. This is within the areas of current establishment of the insects with borderlines fluctuating because of insects spreading from their established zones to areas where temperatures are only seasonally conducive. Simulating an increase in temperature of 2 °C, an expansion of the areas currently invaded by *B. tabaci* can be predicted (Figure 11). Particularly in Spain, France, Italy, Greece and along the Adriatic coast of the Balkans, further insect spread and an increase in *B. tabaci* abundance is expected. Apart from a small area identified in southern Germany (Figure 11), *B. tabaci* will not establish in isolated areas. Even under a climatic change scenario of +2 °C, northern European countries are not likely areas for *B. tabaci* to establish because in these countries suitable thermal conditions do not prevail. This also applies to the PZs of the northern European countries in which climatic conditions outdoors remain unsuitable for whiteflies and thus spread from greenhouse areas to outdoors will remain only seasonal.

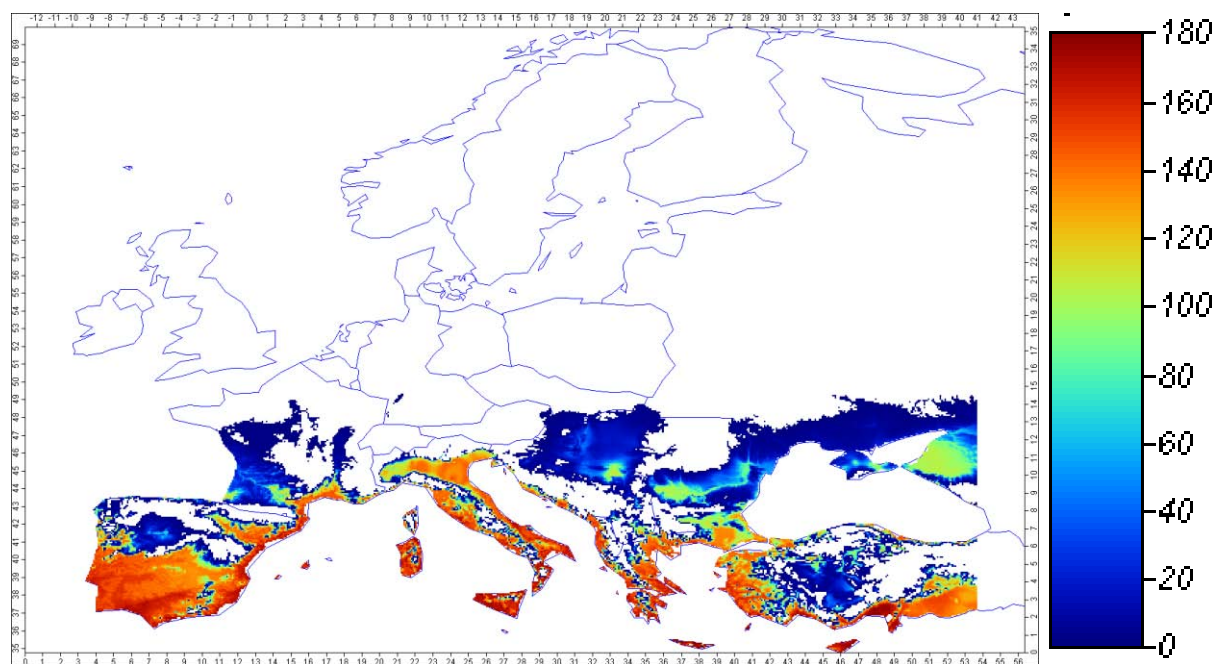


Figure 10: Spatial distribution of the simulated population dynamics of *B. tabaci* in a climate scenario with an increase of temperature of +2 °C of the current climatic situation

The impact of an increase in temperature on the virus is also assessed in the climatic scenario T + 2 °C (see Figure E.4 in Appendix E). Virus spread resembles the dispersal pattern of *B. tabaci* in terms of spatial expansion of areas for virus establishment. An increase in temperature enhances the probability of establishment.

3.4.5. Conclusions on probability of spread

Spread of *B. tabaci* in the RA area mainly depends on climatic conditions and the intensity of trade between EU countries. Long-distance spread is mostly by transport of *B. tabaci* with plant commodities through trade, which also contributes to dissemination of viruses. Spread is rated as moderated likely for *B. tabaci* and the viruses it transmits.

- An expansion of the current invaded outdoor area by *B. tabaci*, as well as an increase of its population density is expected only if the average temperatures in Europe increase. However, even considering a climate change scenario with an increase of on average + 2 °C, *B. tabaci* distribution will expand its most northern limit but still the insect will not establish outdoors in northern EU countries, including those with PZ status.
- In the Mediterranean coastal regions, ample availability of host plants and suitable environmental conditions support spread of *B. tabaci* and its viruses. Because of application of control measures, population densities of *B. tabaci* are kept at low densities which also results in a lower incidence of virus diseases.
- Spread of *B. tabaci* and its viruses to northern EU countries occurs because of the high volume of inter-EU trade and insufficient measures to prevent spread.

Uncertainties concerning spread of *B. tabaci* are rated low because the climate factors limiting outdoor expansion are well known and the northern limits of expansion can be well defined. Medium uncertainty is associated with the rating for virus spread because of the paucity of information on factors driving the epidemics of newly introduced viruses and whether new viruses would express biological features resulting in enhanced vector transmission, rate of replication or host range.

Although there are many effective control options available for *B. tabaci* which also reduce virus problems, they cannot prevent establishment and spread of newly arriving *B. tabaci* and its viruses. Application of control measures can reduce but not eliminate the probability of spread.

Rating <i>B. tabaci</i> and viruses	Justification
Moderately likely	<p>Based on (i) the knowledge on the biology and ecology of <i>B. tabaci</i>, (ii) the volume of trade between the EU countries of plants and plant material; and (iii) the results of model simulations, spread is rated as moderately likely for <i>B. tabaci</i> and the viruses it transmits in the RA area and in the Protected Zones in Europe. This conclusion is based on the following evidence:</p> <ul style="list-style-type: none"> • Under a climatic change scenario of +2°C, the colonized area will globally expand. However, the northern European countries will remain <i>B. tabaci</i> free. • In the northern RA area, host plants are present but <i>B. tabaci</i> do not survive year-round and the climatic conditions for infestation by <i>B. tabaci</i> are unsuitable during a large part of the year. These factors prevent northward expansion of all <i>B. tabaci</i> species and transmitted viruses • In the Mediterranean area, host plants are widely present and the climatic conditions for infestation are often suitable. These conditions facilitate spread of all <i>B. tabaci</i> and transmitted virus species once established. • The probability of spread of new arrived and established MEAM1 or Med <i>B. tabaci</i> within the RA area where the species are already established is high. It is likely that newly arriving insects will merge with already existing specimens of the same species. • The potential of spread of new <i>B. tabaci</i> species is rated as low because of the presence of well-established MEAM1 or Med <i>B. tabaci</i> over large areas and an expected low propagule pressure of new <i>B. tabaci</i> species. • Also new non-European viruses are likely to be transmitted and disseminated with established MEAM1 and Med populations.
	<p>In the Protected Zone</p> <ul style="list-style-type: none"> • The probability of spread of <i>B. tabaci</i> in the PZs is evaluated separately for the northern zone of the PZ and the zone including the regions of Portugal belonging to the PZ. • In northern PZ, the situation is similar to that found in the northern RA areas. In those countries, spread of <i>B. tabaci</i> and transmitted viruses is very unlikely. • In the regions of Portugal included in the PZ (i.e. central and northern parts of Portugal, Madeira and the Azores archipelago), climate and host plant conditions are similar to those found in

	<p>the Mediterranean area. Spread is mainly associated with movements of plants and plant material within this PZ, and to a lesser extent to natural spread of <i>B. tabaci</i>. Thus, spread of <i>B. tabaci</i> and viruses is very likely.</p> <p>In terms of intraspecific and interspecific interactions, the constraints for <i>B. tabaci</i> spread in the PZ are the same as those found in the RA area. Spread depends on the identity of the new <i>B. tabaci</i> versus the already present <i>B. tabaci</i>. This also accounts for transmitted viruses: mixed infections can be lead to interactions resulting in competition or synergism</p>
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3.4.6. Uncertainties on the probability of spread

The *B. tabaci* population dynamics model provides very clear information on the constraint exerted on spread of MEAM1 and Med due to temperature, and the same is expected for new species of *B. tabaci*.

Because Med and MEAM1 are highly invasive and adapted to tomato and other industrially produced crops, uncertainty that a *B. tabaci* species different from MEAM1 and Med would have superior spreading characteristics are low. Uncertainties however related to the lack of knowledge of the invasive potential that might be inherent to *B. tabaci* species other than Med and MEAM1 exist.

Uncertainties are associated with newly emerging viruses for which factors driving epidemic episodes are not yet clear and wild hosts acting as virus reservoirs are not confirmed. It is further unclear whether viruses that are not yet present in Europe and that can infect the crops concerned would have biological features or genetic characters that favour *B. tabaci* transmission or its replication in the host plant. This would provide a selective advantage over existing populations which over time leads to changing virus populations.

For some criniviruses and torradoviruses with loose vector affiliations, uncertainty exists on the significance of *T. vaporariorum*, another whitefly species that transmits damaging plant viruses, for virus spread. Although we considered pathways outside trade to be negligible, uncertainties still exist on the role of passive dispersal via wind streams and human-associated means of transfer not directly linked to host plants trade (vehicles, clothes, etc.).

Rating	Justification
<p><i>B. tabaci</i> Low</p>	<ul style="list-style-type: none"> • The relevant information about the area of spread is sufficient and available for the entire EU, including those countries with PZ status • Uncertainties remain on the dispersal of other <i>B. tabaci</i> species. Although it is assumed that all <i>B. tabaci</i> species have similar climatic requirements and responses, data are only available for MEAM1 and Med species.
<p>Viruses Medium</p>	<ul style="list-style-type: none"> • Uncertainties are associated with newly emerging viruses and the factors driving epidemics are not clear. • It is further unclear whether those viruses that are not yet present in Europe and that can infect the crops concerned would have biological features or genetic characters that favour <i>B. tabaci</i> transmission or its replication in the host plant. This

	<p>would provide a selective advantage over existing populations which over time leads to changing virus populations.</p> <ul style="list-style-type: none"> • For some criniviruses and torradoviruses with loose vector affiliations, uncertainty exists on the significance of <i>T. vaporariorum</i>, another whitefly species which transmits damaging plant viruses, for virus spread.
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3.5. Conclusion regarding endangered areas

In the RA area, the Mediterranean coastal regions are particularly susceptible to the establishment and spread of non-European *B. tabaci* because an almost continuum of host plants and climatic conditions exists, and so might be considered as an endangered area. This endangered area might enlarge, under global change scenario (mean temperature increase of 2°C, Fargues et al., 2006) because of the extension of the northern limits of *B. tabaci* occurrence in open fields. Along with spread of *B. tabaci*, it is likely that the viruses transmitted by this whitefly also move further northwards provided that suitable host plants are present. Since viruses have a more restricted range of host plants than *B. tabaci*, this might limit their spread. When considering tomato and cucurbit crops which are widely grown in Europe, suitable host plants for those viruses infecting tomato and cucurbits are present, in open fields, under protected cultivation and greenhouses of northern European countries. Hence, the entire RA area represents the endangered area when crops grown under protected cultivation are also taken into account.

3.6. Assessment of consequences

Bemisia tabaci is one of the most harmful pests of agricultural and horticultural crops worldwide (Oliveira et al., 2001; Chen et al., 2004; McAuslane et al., 2004). The global spread of the invasive MEAM1 and Med species have had a serious impact on the production of agricultural and horticultural crops, predominantly on those commodities that are produced industrially, particularly tomato and cucurbits but also cotton and ornamentals.

Impact is almost entirely related to diseases caused by *B. tabaci*-transmitted viruses on crops and particularly by those begomoviruses causing yellow leaf curl diseases in tomato, which have a severe impact on crop cultivation and yield in all regions where tomato is grown. The synergy between the two highly invasive whitefly species and TYLCV which is highly infectious to tomato (pepper and beans), efficiently transmitted by *B. tabaci* and adaptable to environments where tomato is cultivated, are characteristics of an invasive virus. Most *B. tabaci*-transmitted viruses cause high impact in crops and generally losses from those virus diseases can be considered as economically very important.

3.6.1. Direct pest effects

Damage is caused by sucking sap from the foliage of plants. Heavy infestations of adults and nymphs can cause seedling death or reduction in vigour of older plants, from sap extraction. Feeding weakens plants and leads to wilting, reduced plant growth (Costa et al., 1993a; Jimenez et al., 1995) and subsequent loss of harvestable yield (Berlinger, 1986). Chlorosis, leaf withering, premature dropping of leaves and plant death also can be a result of heavy whitefly infestations. In particular infestations with MEAM1 *B. tabaci* can be associated with physiological disorders and phytotoxicity effects and, most significantly, the irregular ripening of tomatoes (TIR) and the squash silverleaf disorder (SSD) in many cucurbit crops (Yokomi et al., 1990; Hanif-Khan et al., 1996). TIR was first noted in Florida in 1987 on tomatoes heavily infested with whiteflies. Fruits are discoloured from inhibited or incomplete ripening evident from streaking on longitudinal sections of fruits and/or internal white tissues and hard and unripe fruits (Schuster et al., 1990). TIR symptoms on fruits were not associated with other symptoms but were correlated with high numbers of nymphs and pharate adults on tomato plants (Schuster, 2001) and, the plant developmental stage of the whitefly incursion (McKenzie and Albano,

2009). It has been estimated that, in 1989, Florida tomato growers lost 25 million dollars as a result of TIR (McAuslane, 2005).

SSD was first found in Israel and attributed to drought stress; later in Florida it was associated with the presence of *B. tabaci* and then proven to be a physiological disorder caused by feeding of immature whiteflies (Yokomi et al., 1990; Van de Ven et al., 2000). SSD affects many *Cucurbita* spp. and feeding of whitefly nymphs results in a separation of the upper epidermal cell from the underlying palisade cell layer in newly expanding leaves. This introduces large air spaces leading to the silvery appearance. It spreads systemically in the entire plant and symptom severity is correlated with the number of nymphs feeding (Hoelmer et al., 1991; Schuster et al., 1991). Fruits developing on silverleaved plants are often bleached, and thus of lower grade. SSD is always associated with *B. tabaci* MEAM1 nymphs feeding (Costa et al., 1993b; Schuster et al., 1991), but as shown by De Barro and Khan (2007) prolonged feeding and high infestation of MEAM1 adults can also lead to silverleafing symptoms. SSD is associated only with MEAM1, with other genetic groups, MS (Delatte et al., 2005) and Ug6 (Sseruwagi et al., 2005), also inducing SSD while Med infestations are not associated with silverleafing in cucurbits.

Vein clearing in foliage on poinsettia and a variety of other ornamentals and vegetables has been observed even when low-level colonisation by MEAM1 *B. tabaci* occurs (Brown et al., 1995a). Other disorders caused by *B. tabaci* are lettuce leaf yellowing and stem blanching, carrot light root, pepper streak, *Brassica* sp. white stem and chlorosis of new foliage of many plants (Costa et al., 1993a; Chen et al., 2004) a general chlorosis of cucurbit leaves (Jimenez et al., 1995) and foliage discoloration in many ornamentals (Hoelmer et al., 1991). Chlorotic halos are often to be found, among other plants, on cotton, tomato and squash (Buntin et al., 1993), indicating spots where nymphs had fed.

Indirect feeding damage is caused by the deposit of secretions and this honeydew is a sticky excretory waste that is composed largely of plant sugars, produced by the adult and immature whiteflies. It serves as substrate for black sooty mould on leaves and fruits. The mould reduces photosynthesis and decreases the yields and market value of the vegetables and fruits and the aesthetic quality of ornamentals (Byrne and Bellows, 1991; Davidson et al., 1994). The honeydew can stick cotton lint together, making it more difficult to gin and therefore reducing its value (Henneberry et al., 2000).

3.6.2. Effects of virus infections

Major damage and impact is from *B. tabaci* transmission of plant viruses to highly important food and industrial crops grown in tropical and subtropical regions and in temperate regions of Mediterranean Europe and North America (Morales, 2007). Millions of hectares of crops worldwide and especially tomatoes are affected by whitefly-transmitted viruses most significantly, the circulatively transmitted begomoviruses. Begomoviruses causing leaf curl diseases in tomato threaten tomato production in all production areas in the world, especially in open field cultivation. The most significant viruses among the more than 300 begomovirus species identified to date are TYLCV-like viruses causing TYLCD and those are also most devastating to tomato cultivation in Mediterranean Europe and worldwide (Lapidot and Friedmann, 2002; Abhary et al., 2007; Morales, 2007; Hanssen et al., 2010; Navas-Castillo et al., 2011). Outbreaks of MEAM1 in the Dominican Republic in the late 1980s resulted in severe losses in beans due to bean golden yellow mosaic viruses and in tomato were due to damage from insect feeding, TIR and sooty mould, and also because of infections with begomoviruses (Gilbertson et al., 2007). However it was only the introduction of TYLCV, most likely with imported planting materials that led to a collapse of the tomato production in the Dominican Republic in the early 1990s.

Aside from TYLCV-like viruses, the introduction and emergence of MEAM1 into the Western hemisphere in the mid-1980s resulted in severe outbreaks of diseases caused by a number of begomovirus with serious impact to tomato production in several South American countries and in Florida (Polston and Anderson, 1997). In Florida, the disease caused by tomato mottle virus in 1990 resulted in a 20 % yield loss of the tomato crop amounting to c. USD 125 million losses in tomato

only. In Europe, there are no reports of disease outbreaks from viruses other than TYLCV. However, TYLCD is the limiting factor to tomato production (Lapidot and Friedmann, 2002) especially in Mediterranean countries where tomatoes are produced in greenhouses and in open fields. TYLCV also causes serious diseases in common beans, acting as reservoirs for tomato infections (Navas-Castillo et al., 1999).

The impact of virus diseases caused by virus species from the genera *Crinivirus*, *Ipomovirus* and the recently emerging genus *Torradovirus* has been less well assessed. This is because the discovery of the viruses and their association with plant diseases and crop losses are relatively new and less well understood. With few exceptions, symptoms often are either mistaken for physiological disorders or masked because of the presence of other viruses, such as TYLCV. Infections with criniviruses such as CYSDV that cause yellowing symptoms on the leaves of cucurbits are often confused with nutrient deficiency symptoms. However, consequent damages lead to an approximate yield reduction of 30–50 % (Célix et al., 1996; Hourani and Abou-Jawdah, 2003). In the autumn of 2006, CYSDV was first confirmed in Arizona, causing an estimated 60 % reduction in marketable melon yield (McGinley, 2008). Economic damage estimates from the Arizona Department of Agriculture (James, 2011). The CYSDV outbreak resulted in a USD 18 million loss in melon production within Arizona.

Another crinivirus, BnYDV, caused a disease in greenhouse-grown bean crops in southern Spain that was first observed in 2003 (Segundo et al., 2004), and caused substantial economic losses leading up to 100 % of crop losses. Consequently, many farmers in that region abandoned the cultivation of bean (Janssen et al., 2011). *Ipomovirus* CVYV is considered causing considerable damage in the Middle East and Spain (Arnó et al., 2009). In autumn 2000, CVYV was considered important enough for the Spanish authorities to destroy affected plants covering 70 ha of greenhouses in an attempt to suppress further spread (Cuadrado et al., 2001). Watermelon vine decline (WVD) produces serious economic losses in the watermelon industry. It was first found in Florida in 2003 on squash and is caused by the *ipomovirus* SqVYV (Roberts et al., 2005; Adkins et al., 2007).

The impact from virus infection is major on all the food crops concerned in this RA. This is particularly from circulatively transmitted begomoviruses causing TYLCD in tomato, which can cause a total loss of harvest when viruliferous whiteflies introduce infections on young plants. Other viruses, e.g. non-circulatively transmitted criniviruses, cause growth reductions and severe symptoms on leaves and fruits rendering fruits unmarketable. Invasion of MEAM1 and Med into Europe has resulted in an enormous upsurge in pesticide use from the mid-1990 onwards, associated with insecticide resistance development, ground water contamination and other adverse effects. In many regions, open field production of tomato and cucurbits is not possible because of the abundance of viruliferous insects efficiently transmitting viruses to the crops.

The majority of whitefly-transmitted viruses described so far threaten the cultivation of tomatoes and cucurbits, which are significant food crops for Europe. Although caused by unique and diverse viruses, the diseases are very similar to the yellow leaf curl diseases of tomato in Europe. Severe disease phenotypes from new viruses or viruses with associated satellites, or mixed virus infections are reported for several areas outside the EU. Notwithstanding, there is no scientific evidence indicating replacement/shift of TYLCV populations in Europe or elsewhere.

There is no evidence to assume that more severe viruses are more successful invaders displacing the existing populations of TYLCV in the EU. Several viruses new to Europe have been identified only very recently. Almost all belong to previously not very well studied virus genera: *Crinivirus*, *Ipomovirus* and *Torradovirus*. Although some species in these genera cause serious diseases, epidemics are not well understood. For the most recently described virus species new to Europe, ToTV, establishment has not yet been observed. However, from the biology and association with *B. tabaci* it is supposed that introductions of these viruses into Europe had to involve planting material of tomato and/or cucurbits.

B. tabaci is considered as a pest for the ornamental industry and, although with few exceptions, only *B. tabaci*-transmitted viruses are not known to infect ornamental species, this insect has to be controlled in many production zones in warm climates because of the possibility that insects carry circulatively transmitted viruses. In addition, while some viruses cause only minor disease in one crop e.g. ToCV in tomato, its transmission to potato can result in a major disease.

3.6.3. Environmental consequences

The Panel considers that *B. tabaci* and its associated viruses principally affect crop yield and quality, as we are not aware of publications showing serious pest or disease effects on wild plants in cultivated or natural environments. Environmental side effects are considered to be negligible with low uncertainty in the current area of distribution and in the RA area. *B. tabaci* has been recorded in the Mediterranean area of the EU for a very long time without any evidence of negative consequences on the environment. In general, whitefly species rarely destroy their host plants, because they are kept at low population densities through the combined action of host plant resistance/tolerance and native natural enemies, so they have a low potential for damage to natural ecosystems. *B. tabaci* may temporarily survive on non-crop host plants in areas of Europe where the species cannot overwinter. Also for these areas no reports have been found about negative environmental effects. However, it should be realised that no studies have specifically addressed potential problems caused by whiteflies outside crops.

In the Mediterranean area, where *B. tabaci* can establish outdoors, native whitefly species might be displaced by invasive species, but environmental adverse effects in food webs due to the possible displacement of native species have not been reported. The environmental impact of such potential displacements is considered to be minor as it concerns species that have the same or very similar ecological niches. The most commonly expected environmental effect of these pests is an increased amount and frequency of pesticide applications. Chemical control was the prevailing response to *B. tabaci* presence. Excessive use of insecticides to control *B. tabaci* in cotton in Sudan during the 1970s has resulted in insecticide resistance, but also in a dramatic reduction in populations of the natural enemies of whiteflies and the enemies of other cotton insects, causing secondary pests (Dittrich et al., 1985). A well-known effect, also seen with the use of modern insecticides, e.g. imidacloprid (Nauen et al., 2002; Nauen and Denholm, 2005; Roditakis et al., 2009), is the development of resistance by whiteflies in areas with intensive vegetable production, as in the region of Almeria, Spain. These effects are demonstrated not only for Sudan and Spain, but also for a number of other areas where pesticides were used for whitefly and virus control (Castel et al., 2010), with the aforementioned effect, and also with other effects such as pesticide residues in the environment (mainly water and soil) and impact on non-target organisms, including negative effects on human health (Eveleens, 1983). It is very likely that if the control measures applied are inappropriate, existing biological control systems will be disrupted, native natural enemies might be decimated and pesticide pressure will have negative environmental effects. These environmental consequences are expected to be limited if the control measures are based on (i) biological control by releasing EU native natural enemy species or natural enemies already present, (ii) exclusion nets and yellow sticky traps in greenhouses (which are also widely applied in integrated pest management (IPM) for other major greenhouse vegetable and ornamental crops, i.e. aphids, leafminers, thrips or *Lepidoptera*), (iii) targeted application of selective insecticides with a low toxicological profile to non-target organisms. For details on specific control methods the Panel refers readers to Section 4, Risk reduction options.

B. tabaci is a highly polyphagous herbivore and thus can occur not only in crops but also in natural habitats, private gardens and land for recreation. Generally, the occurrence of pests in uncultivated habitats may pose a threat to crops, as in these habitats control measures are not taken. However, whiteflies have rich natural enemy assemblages in these habitats.

Although viruses may be transferred by *B. tabaci*, these viruses are not known to adversely affect plant species of significant environmental importance. Thus, significant environmental consequences as a result of spread of the viruses to natural environments are not expected. However, control measures to

manage *B. tabaci* as vector of these viruses may involve significant use of insecticides with potential detrimental effects on the environment. Significant environmental consequences as a result of spread of the viruses to natural environments are not expected.

3.6.4. Conclusion on the assessment of consequences

Serious crop diseases are the consequence of infections with viruses transmitted by *B. tabaci* and major consequences to crop production are a result of this whitefly spreading the diseases. Appropriate protection measures need to be in place to limit yield losses and this also includes crops not affected by viruses transmitted by *B. tabaci* (ornamentals) on which, however, insect populations can develop rapidly. Because new types of diseases can be expected from novel viruses and also because begomoviruses evolve rapidly, frequently undergo recombination and also occur as mixed infections, the introduction of viruses can be associated with more severe disease symptoms. The overall assessment of the consequences and damage is only affected by the uncertainty on additional consequences from introduction, establishment and spread of both *B. tabaci* and the viruses it transmits hitherto not present in the RA area. This assessment is associated with a medium level of uncertainty.

The Panel considers that *B. tabaci* and the diseases from viruses transmitted by this insect primarily affect yield and quality of crops. The Panel is not aware of publications demonstrating serious pest or disease effects on wild plants in cultivated or natural environments. The most commonly expected environmental effects are those resulting from inappropriate pesticide applications. Environmental side effects are considered to be negligible with low uncertainty in the current area of distribution and in the RA area.

Rating	Justification
<p><i>B. tabaci</i> as a pest</p> <p>Minor</p>	<ul style="list-style-type: none"> In particular, infestations of the invasive <i>B. tabaci</i> species Med and MEAM1 lead to serious consequences with a major impact on cultivation of significant food crops for Europe: tomato, cucurbits, pepper and beans. While <i>B. tabaci</i> as a pest causes a number of physiological disorders resulting in discoloration of fruits and leaves and reduced quality of fruits and cotton by deposition of honeydew, a major impact is caused by the viruses it transmits. Direct pest effects vary from moderate to high especially as physiological disorders are found on some but not other crops.
<p><i>B. tabaci</i> and viruses it transmits</p> <p>Major</p>	<ul style="list-style-type: none"> The impact from virus infection is major on all food crops concerned in this RA. This is particularly from circulatively transmitted begomoviruses causing TYLCD in tomato. In many regions, open field production of tomato and cucurbits is not possible because of the abundance of viruliferous insects efficiently transmitting viruses to the crops. Other viruses, e.g. non-circulatively transmitted criniviruses, cause growth reductions and severe symptoms on leaves and fruits rendering fruits unmarketable. The enormous upsurge of pesticide use with emerging <i>B. tabaci</i> as a pest was associated with insecticide resistance, ground water contamination and other adverse effects. <i>B. tabaci</i> is considered as a significant pest for the ornamental industry, and this insect has to be controlled in many production

	<p>zones in warm climates because of the possibility that insects carry CVs.</p> <ul style="list-style-type: none"> Some viruses while causing only minor disease in one crop, e.g. ToCV in tomato, contribute to serious diseases in other crops, e.g. ToCV in potato.
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3.6.5. Uncertainties on impact

Rating	Justification
<i>B. tabaci</i> and viruses	
Low	<ul style="list-style-type: none"> While impact for major European food crops concerned in this RA area is high, it differs with plant species, production conditions and crop management. From the global invasion of Med, MEAM1 and TYLCV and the high impact resulting from TYLCD in tomato, the uncertainty whether new <i>B. tabaci</i> and new viruses cause more significant diseases can be rated as low. The uncertainty that infections with viruses not yet present in Europe would result in disease symptoms of otherwise symptomless, virus tolerant tomato cultivars, however is associated with medium uncertainty.

3.7. Conclusions on risk assessments

ENTRY

For entry of *B. tabaci* and the viruses it transmits, five pathways have been identified, and the most relevant one is the plants for planting pathway. Plants not intended for planting (cut flowers and branches with foliage) and the pathway represented by fruits and vegetables were also considered, while entry of *B. tabaci* through human-associated means not involving plants (e.g. on vehicles or clothes) and entry of insects by natural means (e.g. with wind or active flight) were considered negligible pathways and not assessed in this opinion.

Viruses can enter with infected plant material and with insects carrying the viruses (viruliferous insects). Transmission modes of *B. tabaci* transmitted viruses are substantially different and have a strong influence on the probability of entry. Therefore, viruses were grouped into CVs (begomoviruses) and NVs (all other viruses); these two groups are considered separately in the opinion.

The evaluation of entry of pest and viruses was supported with a probabilistic model that combined expert assessment on the presumed risk of entry from the major world areas with trade volumes of commodities related to the three pathways.

Pathway 1. Plants for planting

- Entry of *B. tabaci* can be expected from all world areas where populations of this insect are established, because *B. tabaci* not only is a polyphagous pest infesting a wide range of plant species (host plants) but also can be carried along on non-hosts, that is with plants on which the insect is only visiting or probing (non-host plants).
- The probability of entry of *B. tabaci* into the European Union with the plants for planting pathway is rated as likely, because of the frequent association of insects with the pathway at origin and based on the number of interception records despite strict phytosanitary requirements for places of production of plants for planting. Although the fraction of intercepted consignments relative to the total number of consignments imported in the EU is low, the high trade volumes justify this rating.
- The major volume of trade in this pathway mainly concerns ornamental plants. The specific ornamental plant species that are imported via this pathway are non-host plants for *B. tabaci* transmitted viruses. Entry of CVs can occur with viruliferous *B. tabaci* insects and with infected plants while NVs can enter only with infected host plants, because of their limited persistence in their vector. Entry of viruses with viruliferous *B. tabaci* or with infected crop plants is considered as moderately likely.

Pathway 2. Cut flowers and branches with foliage

- The probability of entry of *B. tabaci* into the EU with the pathway of cut flowers and branches with foliage is considered as moderately likely because eggs and nymphal stages of the pest can survive transport. Short storage periods and the limited vase life of cut flowers reduce the probability of transfer of insects to a suitable host plant. Although the most important cut flower species require phytosanitary inspection and a phytosanitary certificate for import, interceptions still occurs and the high volume of trade justifies this rating.
- Entry of CVs is bound to viruliferous *B. tabaci* adults. Because survival during transport and storage of adult insects is unlikely, the probability that viruses enter via this pathway is considered unlikely. The probability that NVs associated with *B. tabaci* enter into the EU with cut flowers is rated as very unlikely as the ornamentals under concern are non-host plants for these viruses.

Pathway 3. Fruits and vegetables including leafy herbs for consumption

- The probability of entry of *B. tabaci* into the EU with the pathway fruits and vegetables is estimated as unlikely. These commodities intended for consumption are unlikely to present a pathway because of the pathway characteristics (cold chain) and the low probability of transfer to a suitable host after arrival in the EU. This is despite the numbers of specimens intercepted on commodities entering the EU. Because leafy herbs imported alive as potted plants can have a prolonged vase life, a higher risk is associated with these cases and thus the probability of entry of *B. tabaci* would be moderately likely.
- Insects may enter the RA area on vegetables, leafy herbs (specific regulations apply only for *Ocimum* spp. and *Apium* spp.) and on fruits with remaining leaves (e.g. tomato vines).
- Virus entry with *B. tabaci* on fruits, vegetables and leafy herbs is considered very unlikely, because many species used as leafy vegetables and herbs (basil) are not susceptible to *B. tabaci* -transmitted viruses. There also is a very low probability that transfer from virus-infected fruits to suitable host plants would occur. Notwithstanding this, in regions where *B. tabaci* is established outdoors, discarded fruits or peel can be sources of infections and pathways of virus entry.

Information on *B. tabaci* interceptions shows that control measures and phytosanitary requirements in the area of production and inspections have limitations to preventing insects from entry. The limited efficacy of inspections at entry and the high volumes of trade attribute a medium uncertainty to the evaluation of the risk of entry of *B. tabaci*. Uncertainty further exists about aquatic plants entering the EU on which *B. tabaci* is frequently intercepted. The lack of information on their final use in the EU contributes to uncertainty. Because of dual use, some commodities can be assigned either to pathway 2

or to pathway 3. For some species, e.g. *Eryngium sp.*, *Limnophila aromatica*, high rates of interception were observed on cut flowers in the past, but presently these generate interception reports almost exclusively as vegetables and fruit for consumption. Because cut flowers and branches with foliage are subject to more stringent import requirements and fruits and vegetables for consumption are largely not regulated, such changes in the commodity class further contribute to uncertainties on the ratings of the entry pathways for *B. tabaci*.

For viruses transmitted by *B. tabaci* uncertainty exists whether newly introduced ornamental plant species including aquatic plants can be new host plants for hitherto unknown viruses. However, the uncertainties concerning new viruses entering into the EU with any of the pathways can be rated as low.

The application of measures for import consignments which pose a risk seems to be most effective to reduce the probability of entry with all major entry pathways for *B. tabaci*. However interception reports indicate the limitations of the measures.

ESTABLISHMENT

B. tabaci species MEAM1 and Med are established in many parts of the RA area. Since there are many host plant species available for these polyphagous pests, outdoor establishment is limited only by climatic conditions. The assessment of *B. tabaci* establishment is supported by the results of a population dynamics model that was developed with biodemographic temperature-dependent functions estimated for *B. tabaci* in which climate data were used to predict the area of potential establishment of the insect and the viruses it transmits in Europe.

- Assuming similar climatic requirements for all *B. tabaci* species, outdoor establishment of *B. tabaci* including those species entering from outside into the RA area is considered as likely within the areas where *B. tabaci* is already present. Similarly the climatic conditions for crop production in greenhouses favour *B. tabaci* population development and, as proven by records of outbreaks in greenhouses, once *B. tabaci* is introduced it will likely establish.
- In crops such as tomato or cucurbits, Med and MEAM1 are well adapted to the intensive production conditions, and newly invading *B. tabaci* species would probably be less competitive in those crops, but may establish on other plant species. Because *B. tabaci* Med and MEAM1 are highly invasive species and present around the world, it is likely that insects entering into the EU are MEAM1 and Med, and those would merge with existing populations of the same species.

In Europe, several *B. tabaci*-transmitted viruses are present in regions where the insect is established outdoors. Those causing TYLCD are considered to be among the most serious plant viruses in crops.

- Because of the availability of suitable host plants and the presence of efficient vectors, viruses transmitted by *B. tabaci* are likely to establish. This assessment concerns viruses infecting tomato and cucurbit crops which are available almost throughout the year in the production areas of the Mediterranean regions (greenhouses and outdoors) and in the greenhouses of northern EU countries.
- New diseases from recently emerging (novel) *B. tabaci* -transmitted viruses mostly recorded on cucurbits and on tomato provide evidence for newly introduced pathogens and indicate ongoing processes of establishment.
- As far as establishment of other *B. tabaci*-transmitted viruses is concerned, their establishment largely depends on suitable host plants available in the environment and serving as reservoirs for survival and new plant infections. Availability of alternative host plants is not an important requirement for viruses infecting tomatoes and cucurbits.

- Newly introduced begomoviruses infecting tomato would likely contribute to TYLCD, establish mixed virus infections or compete with existing TYLCVs that are highly adapted to tomato.

Uncertainties concerning the assessment of the outdoor establishment of *B. tabaci* are rated as low, because, according to the population dynamic model, estimates of the area of supposed establishment and the northern limits of expansion can be well defined. *B. tabaci* -transmitted viruses are established outdoors in several EU MSs. Uncertainties concerning the establishment of *B. tabaci* in greenhouses are also rated as low because of controlled climatic conditions favouring population development and growth of this insect.

The uncertainty rating for the establishment of newly introduced viruses, however, is considered to be medium because of the limited knowledge about factors driving the epidemics of NVs.

SPREAD

Spread of *B. tabaci* in the RA area mainly depends on climatic conditions and the intensity of trade between EU countries. Long-distance spread is mostly by transport of *B. tabaci* with plant commodities through trade which also contributes to dissemination of viruses. Spread is rated as moderately likely for *B. tabaci* and the viruses it transmits.

- An expansion in the current outdoor area invaded by *B. tabaci*, as well as an increase in its population density is expected only if the average temperatures in Europe increase. However, even considering a climate change scenario with an increase of on average + 2 °C, *B. tabaci* distribution will expand its most northern limit but still the insect will not establish outdoors in northern EU countries, including those with PZ status.
- In the Mediterranean coastal regions, the ample availability of host plants and suitable environmental conditions support the spread of *B. tabaci* and its viruses. Because of application of control measures, population densities of *B. tabaci* are kept at low densities, which also results in a lower incidence of virus diseases.
- The spread of *B. tabaci* and its viruses to northern EU countries occurs because of the high volume of inter-EU trade and insufficient measures to prevent spread.

Uncertainties concerning the spread of *B. tabaci* are rated low because the climate factors limiting outdoor expansion are well known and the northern limits of expansion can be well defined. Medium uncertainty is associated with the rating for virus spread because of the paucity of information on factors driving the epidemics of newly introduced viruses and whether new viruses would express biological features resulting in enhanced vector transmission, rate of replication or host range.

Although there are many effective control options available for *B. tabaci* that also reduce virus problems, they cannot prevent establishment and spread of newly arriving *B. tabaci* and its viruses. Application of control measures can reduce but not eliminate the probability of spread.

IMPACT

Serious crop diseases are the consequence of infections with viruses transmitted by *B. tabaci*, and major consequences to crop production are a result of this whitefly spreading the diseases. Appropriate protection measures need to be in place to limit yield losses and this also includes crops not affected by viruses transmitted by *B. tabaci* (ornamentals) on which, however, insect populations can develop rapidly. Because new types of diseases can be expected from novel viruses and also because begomoviruses evolve rapidly, frequently undergo recombination and also occur as mixed infections, the introduction of viruses can be associated with more severe disease symptoms. The overall assessment of the consequences and damage is only affected by the uncertainty on additional consequences from introduction, establishment and spread of both *B. tabaci* and the viruses it

transmits hitherto not present in the RA area. This assessment is associated with a medium level of uncertainty.

The Panel considers that *B. tabaci* and the diseases from viruses transmitted by this insect primarily affect the yield and quality of crops. The Panel is not aware of publications demonstrating serious pest or disease effects on wild plants in cultivated or natural environments. The most commonly expected environmental effects are those resulting from inappropriate pesticide applications. Environmental side effects are considered to be negligible with low uncertainty in the current area of distribution and in the RA area.

Summary of ratings on the pest risk assessment stages

Risk assessment stage	Area	Rating of risk		Rating of uncertainties	
		<i>B. tabaci</i>	Viruses	<i>B. tabaci</i>	Viruses
Entry	EU Member States covered by Annex IAI regulation	Likely	Moderately likely	Medium	Low
	Countries with PZ status under Annex 1B regulation	Moderately likely	Moderately likely	Medium	Low
Establishment	EU Member States covered by Annex IAI provisions	Likely	Likely	Low	Medium
	Countries with PZ status under Annex 1B regulation (excluding Portuguese islands – see Section 3.3.7.)	Very unlikely	Very unlikely	Low	Medium
	Regions of Portugal included in the PZ	Likely	Likely	Low	Medium
Spread	EU Member States covered by Annex IAI provisions	Moderately likely	Moderately likely	Low	Medium
	Countries with PZ status under Annex 1B regulation (excluding Portuguese islands – see Section 3.4.5.)	Very unlikely	Very unlikely	Low	Medium
	Regions of Portugal included in the PZ	Very likely	Very likely	Low	Medium
Potential consequences	Entire RA area	Minor	Major	Medium	Medium

4. Risk reduction options for *B. tabaci* and the viruses it transmits

4.1. Introduction

In this section the Panel analyses the current legislation (Section 4.2) and its effectiveness (Section 4.3), provides a summary of RROs for *B. tabaci* and the viruses it transmits (Section 4.4), evaluates the current phytosanitary measures and proposes additional risk reductions options (Section 4.5), and draws several general conclusions (Section 4.6). The Panel used the classification of RROs as presented in the EFSA guidance document on methodology for assessment of the effectiveness and technical feasibility of options to reduce the risk of introduction and spread of organisms harmful to plant health in the EU territory (EFSA, Panel on Plant Health (PLH), 2012). For each group of RROs the Panel provides conclusions on the effectiveness and technical feasibility of the RROs and the uncertainties associated with the assessment in summarising tables in this section. A more extensive overview of the RROs can be found in Appendix F.

4.2. Current legislation

The current legislation, laid down in Council Directive 2000/29/EC, makes a distinction between non-European and European populations of *B. tabaci*. Non-European populations are listed in Annex 1, Part A, Section I, of Council Directive 2000/29/EC as “harmful organisms, not known to occur in any part of the community and relevant for the entire community, whose introduction into, and spread within, all Member States shall be banned”. European populations are listed in Annex I, Part B as “harmful organisms whose introduction into, and spread within, certain protected zones shall be banned”. Viruses transmitted by *B. tabaci* are listed in Annex 1, Part A, Section I, of Council Directive 2000/29/EC and are therefore considered as “harmful organisms, not known to occur in any part of the community and relevant for the entire community, whose introduction into, and spread within, all Member States shall be banned”.

For plants, plant products and other objects originating *outside* the Community, special requirements for their introduction and movement into and within all Member States are formulated in Annex IV, Part A, Section I, of Council Directive 2000/29/EC, to prevent introduction and spread of *B. tabaci* (non-European populations) and viruses transmitted by *B. tabaci*:

- in point 45.1 and point 45.2, targeted at the absence of *B. tabaci* (non-European populations) in specified plants originating in non-European countries
- in point 45.3, targeted at the absence of TYLCV in plants of *Lycopersicon lycopersicum*.
- In point 46, targeted at the absence of viruses transmitted by *B. tabaci* in plants intended for planting, other than seeds, bulbs, tubers, corms and rhizomes, originating in countries where these viruses are known to occur.

For plants originating *in* the Community, special requirements for the introduction and movement into and within all Member States are formulated in Annex IV, Part A, Section II, of Council Directive 2000/29/EC only for plants of *Lycopersicon lycopersicum*, intended for planting, other than seeds, to prevent spread of TYLCV:

- In point 26.1, targeted at the absence of TYLCV in these plants.

Additional special requirements for the introduction and movement of plants, plant products and other products into and within certain PZs have been formulated in Annex IV, Part B, to prevent introduction and spread of *B. tabaci* (European populations) into and within these PZs. These requirements apply to *E. pulcherrima*, *Begonia*, *Hibiscus* and *Ficus* plants for planting in professional plant production and not intended for end use.

The legislation makes a distinction between European and non-European populations of *B. tabaci*. The term “non-European *B. tabaci* population” is used to denote the origin of the insect(s) associated with

a particular consignment rather than providing a characteristic for specimen differentiation. The currently available diagnostic tools allow identification and discrimination between *B. tabaci* species, but they cannot be used in routine checks by phytosanitary services. It has been shown that there are species of *B. tabaci* that are not present in Europe but are endemic to specific geographical areas. From the four *B. tabaci* species identified in Europe, the MEAM1 and Med species are highly invasive on a global scale and are almost always present wherever climatic conditions are suitable. When introduced, these “European populations” of MEAM1 and Med displace or eliminate existing populations and are implicated in serious virus epidemics in tomato and cucurbits, as well as in other crops around the globe. Reports on *B. tabaci* interceptions in Europe do not provide specific information on the species identified but it is highly likely that the *B. tabaci* concerned were either MEAM1 or Med, thus species already present in Europe. For other *B. tabaci* species endemic to Asia, Africa or South America and not yet present in Europe, there is no scientific proof that they exhibit biological features considerably different from *B. tabaci* from Europe. All evidence shows however that MEAM1 and Med present in Europe are worldwide the most invasive *B. tabaci* species.

Entry of *B. tabaci* originating from outside Europe is associated with the risk that the insects carry exotic viruses. These viruses may enter the EU either with infected host plants or, viruliferous adults on commodities that sustain their survival during transport and storage. This risk is associated with all *B. tabaci* species, with minor differences regarding vector competence and transmission efficiency. Virus spread is assured by high numbers of insects and/or a circulative transmission mode.

4.3. Effectiveness of the current legislation

The current legislation prohibits the entry of non-European populations of *B. tabaci* and all viruses it transmits, stipulating special requirements for plants for planting, cut flowers and leafy vegetables. For *B. tabaci*, objective identification and differentiation criteria to accurately assign populations have become available, so a distinction between European and non-European populations can be made although its significance is questionable. This is because of similar biological characteristics (although data are limited for specific species), climatic requirements and the ability to transmit plant viruses. The widespread occurrence of *B. tabaci* species MEAM1 and Med especially in countries with major trade with Europe (e.g. Israel) makes it very likely that whiteflies entering are species already present in Europe and thus blend in. Non-European *B. tabaci* populations have climatic requirements similar to Med and MEAM1, hence establishment would be in areas already occupied by these species. Med and MEAM1 show superior invasiveness especially in those crops such as tomato and cucurbits that are industrially grown on, hence establishment of non-European *B. tabaci* would be expected mainly in niches that are not already occupied. In Europe, *B. tabaci* is established outdoors only in the Mediterranean coastal regions. Even under temperature increase scenarios that predict expansion of the areas of establishment, new focal points of invasion, outwith these regions are not expected. Application of pest management methods to reduce *B. tabaci* populations in Europe is adequate, hence an additional impact from the introduction of further *B. tabaci* species is not expected.

Considering *B. tabaci*, the current legislation provides only limited protection from entry into Europe owing to the extensive volumes of commodities moving in trade, especially of ornamental plants for planting and cut flowers. *B. tabaci* sometimes evades detection since nymphs and eggs are difficult to see. Because of the global problems with *B. tabaci* in warm climates, lifting the regulations would have the immediate consequence of association of high numbers of *B. tabaci* with all consignments of host plants. This might not be a problem with regard to the *B. tabaci* in Europe, but it will definitely increase the risk of entry of new viruses.

Considering entry of viruses, outbreaks of virus infections from imports of infected plants for planting and of *B. tabaci* viruliferous for TYLCV provide an indication that both pathways of virus entry into new areas exist. The current legislation cannot fully prevent this entry. Entry of viruses that are non-circulatively transmitted by *B. tabaci* is most likely with virus-infected planting materials only and thus it can be considered that these viruses either have entered with ornamentals not showing symptoms or, more likely, with their tomato or cucurbit hosts.

For circulative viruses persisting in *B. tabaci*, there is currently no record of introduction into EU MSs resulting in outbreaks of new begomoviruses or TYLCV despite the number of interceptions of *B. tabaci* on commodities from all pathways including ornamental plants for planting, leafy herbs and fruits and vegetables. This is probably because it is very unlikely for viruliferous whiteflies to find tomato and/or cucurbit hosts or any other plant host susceptible for a particular begomovirus. When virus is introduced with viruliferous whiteflies on ornamentals, production sites for ornamentals and for tomato and cucurbit vegetables have to overlap for the viruliferous *B. tabaci* to infect susceptible crops because ornamentals of concern are generally considered not susceptible to *B. tabaci* -transmitted viruses. However, the large number of newly described whitefly-transmitted begomoviruses and the ever-changing portfolio of ornamental species traded make it very difficult to predict whether a particular ornamental plant is also a virus host. Hence, lifting the regulations would have the consequence that inspections at origin would be relaxed, monitoring for virus symptoms would be much less stringent and the risk of new viruses entering from endemic zones would increase.

The effectiveness of the current regulation in preventing entry of viruses transmitted by *B. tabaci* is limited because the special requirements for import rely on observation of symptoms. Symptoms can provide good indications, but absence of symptoms is not a proof of virus freedom. Viruses, especially criniviruses, can remain latent in their hosts or induce symptoms that remain inconspicuous at production sites. For other virus host plants such as tomato, symptoms are barely noticeable on young plants and become apparent only about 10–14 days after inoculation by *B. tabaci*. This also applies to tomato grafted on infected rootstocks. Young infected tomato plants for planting will generally show obvious symptoms only after transplantation and during the production cycle (TYLCV in Netherlands, ToTV in Poland). Similarly, infections of tomato, cucurbits and beans with criniviruses, carlaviruses and ipomoviruses, remain inconspicuous in young plants but eventually result in serious virus diseases. However, since the host range of these viruses is very restricted, the effectiveness of the current regulation can be supported by existing voluntary diagnostic protocols (EPPO) for viruses and host plants.

Because of host-range restrictions and the presence of particular host plants in Europe, the most important whitefly-transmitted viruses are those causing damage to tomato, cucurbits and beans. In the main production zones of these crops cultivation is not possible without a comprehensive pest and disease management in place to control *B. tabaci* and the viruses it transmits and this will likely also be effective against newly entering viruses. However, if the current regulation would be revoked, the risk of introduction of new viruses infecting tomato and other crops would significantly increase and damage is expected especially from unrelated viruses, e.g. ToTV, which were previously not specifically listed or considered.

4.3.1. Protected zone status

Bemisia tabaci is established in the Mediterranean coastal regions and, even with an estimated temperature increase of 2 °C, expansion of areas where the pest can establish will be still very distant from the northern European countries with PZ status, Ireland, United Kingdom, Sweden and Finland. The PZ status for Portuguese islands in which climatic conditions are suitable for *B. tabaci* is maintained only by exclusion of the pest.

With the current regulation in place, there are still a significant number of interceptions reported for *B. tabaci* on ornamental commodities from third countries and from intra-EU trade. The latter also comprises entry of *B. tabaci* from third countries via European trade partners.

For northern countries with PZ status, there is no risk of establishment of *B. tabaci* outdoors, but direct pest damage to, for example, poinsettias could be a consequence. For viruses entering with *B. tabaci* on ornamentals or, for example, with TYLCV-infected *Lisianthus*, there is a risk of outbreaks only when tomato and ornamentals are grown in the same environment at the same time. Such TYLCV outbreaks can be efficiently eliminated, as exemplified by an eradication campaign conducted in the Netherlands in 2007 (NPPS, 2007).

If the PZ status regulation was to be lifted for PZ countries, restrictions from Annex IV, Part A banning introduction and spread of non-European *B. tabaci* populations would still apply although probably be modified by the current knowledge about *B. tabaci* species. Revoking the status would place PZ countries in a similar position to other northern countries where *B. tabaci* cannot establish, responding to outbreaks rather than maintain pre-emptive measures including eradication, statutory inspections, etc. A free flow of EU-traded commodities, however, will likely increase occurrences and outbreaks of *B. tabaci* and with that the likelihood that viruses are transmitted to significant crops, tomato and cucurbits, causing high impact and severe crop losses.

Maintaining the PZ status with the current 1A status partially or entirely lifted would still support the “zero tolerance” approach towards *B. tabaci*, regardless of its origin with the benefit of a significantly reduced risk of entry of *B. tabaci* and the viruses it transmits.

4.4. Overview of risk reduction options for *B. tabaci* and the viruses it transmits, including current phytosanitary measures

4.4.1. RRO category 1. Options for consignments – prohibition

Current situation in the EU Currently the introduction into the EU of plants, plant products and other objects, specified by Council Directive 2000/29/EG Annex III, Part A, is prohibited. Some of these commodities are host plants of *B. tabaci* and/or the viruses it transmits, but the majority of host plants are not included in the Annex.

Comments from Panel Theoretically, prohibition of import of host plant commodities is very effective in reducing the risk of entry of both *B. tabaci* and the viruses it transmits. The technical feasibility, however, is low because of the large host plant range of the pest. Further, *B. tabaci* transmits more than 300 distinct plant viruses (Navas-Castillo et al., 2011). The uncertainty of these ratings is low.

4.4.2. RRO category 2. Options for consignments – pest freedom: inspection or testing

Current situation in the EU According to Annex V, Part B, of Council Directive 2000/29/EC, a plant health inspection is required in the country of origin or the consignor country before entry into the EU for consignments of all plants for planting and for consignments of specified parts of plants of a number of listed plant species, other than plants for planting. According to Annex IV, Part A, Section I, of Council Directive 2000/29/EC, a specific statement on the absence of *B. tabaci* is required in addition to the plant health inspection for consignments of cut flowers or leafy vegetables of specified plant species. There are no specific requirements with respect to *B. tabaci* for inspection of consignments of plants for planting. There are also no specific requirements with respect to viruses transmitted by *B. tabaci* for inspection of consignments. Part B of Annex IV lists the requirement for introduction and movement of consignments into PZs within the Community (see appendix F). There are no requirements for testing of consignments.

Comments from Panel Inspection of regulated consignments is performed prior to export and at the point of entry in the PRA area, or at other points determined by NPPOs.

Inspection of consignments of regulated articles moving in trade is an essential tool for the reduction of pest risks and is the most frequently used phytosanitary procedure worldwide. The International Standard for Phytosanitary Measures (ISPM) No 31 (FAO, 2009a) provides guidance on appropriate sampling methodologies for inspection or testing of consignments/lots. Detection of *B. tabaci* and viruses depends on inspections of plants for eggs, nymphs and adult whiteflies and on manifestation of virus disease symptoms. The accuracy of detection also depends on sample size, which is currently not specified in the Directive. The EU legislation and the ISPMs of the International Plant Protection Convention (IPPC) do not require a minimum confidence level for inspection of consignments, but the commonly used confidence levels in sampling cannot guarantee pest freedom.

During visual inspection of the plants, eggs and young instars of *B. tabaci* may remain undetected owing to their small size and transparent colour. Adults present at low densities may also remain undetected. Further, misidentification with related species, such as *T. vaporariorum*, can decrease the effectiveness of inspection. Therefore the effectiveness of inspection in detecting *B. tabaci* is medium. Visual inspection of plants for the presence of viruses is not reliable because disease symptoms can remain inconspicuous or may be absent, hence viruses may remain undetected. Thus identification and detection of viruses transmitted by *B. tabaci* in plants and in their vector insects can only be done reliably with appropriate virus assays conducted in the laboratory. The effectiveness of virus inspections therefore is assessed as low and, when laboratory testing is conducted, the effectiveness is considered as medium. The feasibility of consignment inspection is high, both for *B. tabaci* and the viruses it transmits. The feasibility of consignment testing is medium to low, depending on the commodity, because of the required time for laboratory testing.

Even though the current regulations require official inspection, the methods to confirm absence or establish presence of the pest are not clearly specified. In most cases, it is a responsibility of the NPPOs to decide on the sampling procedures and the frequency of inspections. Thus, even if a particular set of inspection procedures is considered adequate by an NPPO, it may not be sufficient to detect *B. tabaci* and/or its viruses, especially when dealing with large volumes/crop areas and low population densities. Because the effectiveness of inspection is strongly affected by the unknown performance of procedures, the uncertainty of these ratings is medium for *B. tabaci*. The uncertainty for the ratings of viruses is low.

4.4.3. RRO category 3. Options for consignments – prohibition of parts of the host or of specific genotypes of the host

Current situation in the EU Council Directive 2000/29/EC states that a number of plant species which are exported to the EU should be free from flowers and fruits (see appendix). However, there is no prohibition on the import of parts of the host plants or of specific genotypes of host plants with respect to *B. tabaci* or the viruses it transmits.

Comments from Panel All life stages of *B. tabaci* are usually found on the underside of leaves (Bedford et al., 1994). The most resistant stage, which has the greatest chance of surviving transportation and storage, is the last nymphal stage of *B. tabaci*. Therefore removal of flowers and fruits will not have any effect if the pest is present on the planting material. Many viruses transmitted by *B. tabaci* (especially begomoviruses) cause systemic infections of the plant host (Saeed et al., 2005; Kon et al., 2009) and therefore prohibition of specific parts of the host would not reduce the risk of virus entry. Unless leaves are prohibited, this measure would have no effect in reducing the risk of entry of *B. tabaci*. However, such a measure would not be feasible for planting material. Regarding tomato fruit, *B. tabaci* can be carried on remaining green parts such as leaves (tomatoes on the vine), and in the case of very high population density at the place of production, on sepals and peduncles. If the commodity originates from countries where TYLCV is present, there is a risk of entry of viruliferous *B. tabaci* in the PRA area. A requirement for removal of green parts attached to fruit would effectively minimise the risk of entry of *B. tabaci*.

For viruses causing systemic infections, which comprise the majority of *B. tabaci* -transmitted viruses, prohibition of parts or specific genotypes of the host will have no effect in reducing the risk of entry. The effectiveness and feasibility for *B. tabaci* and for the viruses it transmits are assessed as low, with low uncertainty.

4.4.4. RRO category 4. Options for consignments – pre-entry or post-entry quarantine system

Current situation in the EU The current regulations do not require pre-entry quarantine for hosts of *B. tabaci* and the viruses it transmits. Nevertheless, in some cases, there are requirements for compulsory growing periods prior to export. Council Directive 2000/29/EC explicitly requires two years of growing in registered nurseries for naturally or artificially dwarfed plants for planting prior to

export. In case *B. tabaci* has been found on plants for planting of several herbaceous species, the Directive requires appropriate treatment to ensure pest freedom and official inspections weekly during the nine weeks prior to export. The obligation of a post-entry quarantine period is considered as a possible protective measure in Article 13c of Directive 2000/29/EC.

Comments from Panel In general, pre- and post-entry quarantine systems can be very effective in checking for the presence of harmful organisms. The current EU regulation of a nine-week pre-entry monitoring period for herbaceous hosts found infested with *B. tabaci* is not a true pre-entry quarantine system, because this would require a closed environment. However, the Panel agrees that this monitoring period is sufficient to ascertain whether the pest has been eliminated from the place of production, as *B. tabaci* can complete two or three generations during these nine weeks (see Section 3.1, Pest categorisation). The effectiveness and feasibility of this monitoring period are assessed as high. Uncertainty is medium because the effectiveness depends on the meticulousness in performing the eradication treatments and subsequent monitoring. The interceptions of *B. tabaci* in plants for planting suggest that these requirements are not always met. The effectiveness of a true pre-entry or post-entry quarantine system is assessed as high, both for *B. tabaci* and the viruses it transmits, but feasibility is assessed as low due to the long period required for virus expression and testing for viruses in combination with the large number of consignments that have to be placed in these closed quarantine systems. The uncertainty is assessed as low.

4.4.5. RRO category 5. Options for consignments – phytosanitary certificates and other compliance measures

Current situation in the EU Council Directive 2000/29/EC requires issuing of phytosanitary certificates in the country of origin for all plant species and plant products listed in Annex V, Part B of the Directive (see appendix F). For plants listed in the Annex IV, Part A, Section I, in addition to issuing a phytosanitary certificate, other special requirements need to be met.

Comments from Panel Phytosanitary certificates represent official declarations on behalf of the country of origin that exported consignments do not harbour harmful organisms. However, ensuring pest freedom of the consignments requires reliable inspection/testing and, in the case of infestation and/or disease, appropriate measures to eliminate the pest. Demanding guarantees for pest freedom from the exporting country is a very efficient measure against the entry of *B. tabaci* and the viruses it transmits, provided that the chosen methods for inspection and treatment are fully effective. Tomato fruit, which are associated with the risk of entry of TYLCV, are not regulated by the Directive. However, tomato fruit with green parts such as sepals, peduncles and leaves (tomatoes on the vine) can also carry *B. tabaci*, thus facilitating transfer of the virus to other hosts (Delatte et al., 2003). The panel considers that, if a phytosanitary certificate is required for this commodity, the risk of entry of TYLCV and *B. tabaci* associated with it would significantly decrease. The feasibility of this RRO is high for *B. tabaci* and the viruses it transmits, but uncertainty of these scores is medium depending on the performance of the required measures.

4.4.6. RRO category 6. Options for consignments – preparation of the consignment

Current situation in the EU Annex IV, Part A, Section I of Council Directive 2000/29/EC requires cleaning of trees and shrubs, annual and biennial plants, other than Gramineae, and herbaceous perennial plants for planting of families Caryophyllaceae, Compositae, Cruciferae, Leguminosae and Rosaceae from flowers and fruits. More complex preparations are required for artificially dwarfed plants for planting (item 43), including cleaning, planting on treated media and packing in closed containers with registration plates.

Comments from Panel Although these measures are not specifically targeted at *B. tabaci* or the viruses it transmits, cleaning of plants with water and removal of older leaves will have a minor effect on *B. tabaci*, by reducing its abundance to some extent but will not have any effect on established

virus diseases. For *B. tabaci* and the viruses it transmits the effectiveness is low and feasibility is high, with low uncertainty for these scores.

4.4.7. RRO category 7. Options for consignments – specified treatment of the consignment/ Reducing pest prevalence in the consignment

Current situation in the EU Current legislation does not require this option, as all commodities should be free of the pest prior to export (i.e. before packing). Therefore, treatment of consignments is not relevant for *B. tabaci* and the viruses it transmits.

Comments from Panel The current EU measures require that all plants for planting that are hosts of *B. tabaci* are free from the pest prior to export. Therefore, consignments should be free of the pest *per se*. Treatment of consignments to eliminate *B. tabaci* is often not realistic as it interferes with product quality. For viruses, there is no treatment method available. For *B. tabaci* the effectiveness and feasibility are low with low uncertainty; for the viruses it transmits the option is not applicable.

4.4.8. RRO category 8. Options for consignments – restriction on end use, distribution and periods of entry

Current situation in the EU No RROs are listed in the Directive concerning this category

Comments from Panel Any restrictions on the periods of entry of consignments will have no effect on the risk of entry of *B. tabaci*, as it may develop in greenhouses all year long as well as outdoors in large parts of the southern Mediterranean area. The option is neither applicable for *B. tabaci*, nor for the viruses it transmits.

In the Table 17 the Panel presents a summary of options for consignment (RROs 1-8).

Table 17: Summary of options for consignment (RROs 1-8). For more detail on each of the method mentioned in this table, see the text under RRO category 1-8 in the Appendix F. For a description of the terms used in this table and for the ratings, see Tables 20 - 23 at the end of the section on RROs.

Options for consignment	Effect on <i>Bemisia</i> /Uncertainty	Effect on virus /Uncertainty	Applicability	Feasibility
1. Prohibition of consignments	massive / low	massive / low	low	low
2. Inspection or testing	massive / low	major / low	medium	high
3. Prohibition of parts	minimal / low	minimal / low	medium	low
4. Pre-entry quarantine	massive / low	moderate / low	high	high
Post-entry quarantine	major / low	moderate / low	high	high
5. Demand for phytosanitary certificate	major / low	moderate / low	High	high
6. Preparation of consignment	minor / low	minimal / low	medium	low
7. Specified treatment of consignment	major / low	minimal / low	medium	low
8. End use	minor / low	minor / low	low	low
Distribution	minimal / low	minimal / low	low	low
Periods of entry	minimal / low	minimal / low	low	low

4.4.9. RRO category 9. Options preventing or reducing infestation in the crop - treatment of the crop, field, or place of production in order to reduce pest prevalence

Current situation in the EU In case signs and symptoms of *B. tabaci* are detected in herbaceous plants for planting prior to export, Annex IV, Part A, Section I of Council Directive 2000/29/EC requires appropriate treatment of the place of production to ensure pest freedom. In countries where *B. tabaci* and TYLV are both known to occur, the place of production of tomato plants for planting must have been subjected to appropriate treatment to ensure freedom of *B. tabaci*. Additionally, all plants for planting, originating from countries where viruses transmitted by *B. tabaci* occur and where *B. tabaci* is also present should come from areas or production places found free from *B. tabaci* or, in case of *B. tabaci* infestation, be treated for eradication of the pest. With respect to PZ countries several plant species (see appendix F) should be subjected to appropriate treatment to ensure pest freedom.

Comments from Panel Even though appropriate treatment to eliminate *B. tabaci* is required, it is not clear what methods should be used. Treatment procedures carried out in the countries of origin may not be fully efficient, especially in areas with a warm climate where *B. tabaci* is ubiquitous and develops quickly both in protected environments and outside. Another difficulty in eliminating the pest is that the treatment programme must be targeted at all life stages, while most plant protection products act only on specific stages.

The Panel provides an extensive overview of numerous options (cultural methods, biological control and chemical control) to prevent or reduce infestation of the crop in Appendix F. At the end of this paragraph, the Panel presents a table with an overview of the options (Table 18). Many of the options can be applied at different stages of handling commodities: during cultivation, packaging, export, import, storage and distribution. Treatment with one or a combination of these options demanded by the importing country, can be a requirement to prevent entry and/or be implemented at the point of import to prevent establishment and spread. Use of these options—together with options mentioned under other RRO categories—in IPM programmes may generally result in effective management of *B. tabaci* and the viruses it transmits. Two examples of successfully used IPM programmes are given in Appendix F.

Table 18: Summary of options preventing or reducing infestation in the crop: Treatment of the crop, field, or place of production to reduce pest prevalence. For more details see the text under RRO category 9 in the Appendix F. For a description of the terms used in this table and for the ratings, see Tables 20 - 23 at the end of the section on RROs.

Options to prevent/reduce infestation	Effect on <i>Bemisia</i> / uncertainty	Effect on virus/ uncertainty	Applicability	Feasibility
Cultural method				
Crop free period	Major / medium	Major / medium	High	High
Planting date	Minor / medium	Minor / low	High	High
Sanitation before planting	Major / medium	Major / medium	High	High
Plant manipulation before planting	Minor / low	Minimal / low	High	High
Pruning	Minor / low	Minimal / low	Medium	Medium
Roguing / removal of virus infected plants	Minor / low	Moderate / low	High	High
Weed management	Minor / low	Minor / low	Medium	Medium
High planting density	Minimal / low	Minimal / low	Low	Low
Barriers/mechanical control	Minimal / low	Minimal / low	Low	Low
Intercropping	Minimal / low	Minimal / low	Low	Low
Mulching	Moderate / medium	Minor / medium	Low	Low
Fertilization/plant nutrition	Minor / medium	Minimal / minimal	Low	Low
Irrigation/water stress	Minimal / low	Minimal / low	Low	Low
Overhead irrigation	Minimal / low	Minimal / low	Low	Low
Sanitation, disposal of crop residues	Major / low	Major / low	High	Medium
Scouting	Major / medium	Major / medium	High	High
Biological control				
<i>Encarsia lutea</i>	Minimal / high	Minimal / low	Low	Low
<i>Encarsia pergandiella</i>	Minor / high	Minor / low	Low	Low
<i>Eretmocerus eremicus</i>	Minor / medium	Minor / low	Medium	Medium
<i>Eretmocerus mundus</i>	Major / low	Minor / low	High	High

<i>Amblyseius swirskii</i>	Massive / low	Minor / low	High	High
<i>Coenesia attenuata</i>	Minor / high	Minimal / low	Low	Low
Coccinellids	Minimal / high	Minimal / low	Low	Low
<i>Dicyphus tamaninii</i>	Moderate / medium	Minor / low	Medium	Medium
<i>Macrolophus pygmaeus</i>	Major / low	Minor / low	High	High
<i>Nesidiocoris tenuis</i>	Massive / low	Minor / low	High	High
Anthocoridae (<i>Orius</i> spp)	Minimal / high	Minimal / low	High	High
Entomopathogenic fungi	Mmajor / medium	Minor / low	High	High
Chemical control				
Acetylcholinesterase (AChE) inhibitors: carbamates and organophosphates	Major / low	Moderate / low	High	High
Sodium channel modulators: pyrethroids	Moderate / low	Moderate / low	High	High
Nicotinic acetylcholine receptor (nAChR) agonists: neonicotinoids	Massive / low	Major / low	High	High
Nicotinic acetylcholine receptor (nAChR) agonists: sulfoxaflor	Massive / medium	Moderate / low	High	High
Juvenile hormone mimics: pyriproxifen	Major / low	Minor / low	High	High
Selective homopteran feeding blockers: pymetrozine	Major / low	Major / low	High	High
Inhibitors of chitin biosynthesis, type 1: buprofezin	Major / low	Minor / low	High	High
Mitochondrial complex I electron transport inhibitors	Major / low	Moderate / low	High	High
Inhibitors of lipid synthesis	Massive / low	Minor / low	High	High
Ryanodine receptor modulators	Massive / low	Major / low	High	High
Azadirachtin	Moderate / medium	Minor / low	High	High
Oils	Moderate / medium	Minor / low	High	High
Soaps	Moderate / medium	Minor / low	High	High
Integrated Pest Management	Massive / low	Massive / low	High	High

4.4.10. RRO category 10. Options preventing or reducing infestation in the crop – resistant or less susceptible varieties. Host-plant resistance to *B. tabaci* and/or viruses it transmits

Current situation in the EU This option is not addressed in Council Directive 2000/29/EC.

Comments from Panel Use of host plant resistance to control *B. tabaci* and the viruses it transmits has been proposed by many authors (e.g. Gerling, 1990; Gerling and Mayer, 1996; Morales, 2001; Lapidot and Friedman, 2002; Stansly and Naranjo, 2010) and is the topic of fundamental and applied scientific research. Wild tomato species and cultivars of tomato and a number of other crops have been identified with apparent (partial) resistance to *B. tabaci* infestation and to the viruses it transmits (Nombela and Muñiz, 2010).

According to many scientific studies, host plant resistance against *B. tabaci* and its viruses offers great prospects. Tomato cultivars tolerant to virus diseases, sustaining normal growth and fruit production, are commercially available and a basic component of IPM especially in areas where *B. tabaci*-transmitted viruses are endemic. Tolerant cultivars have been particularly effective in reducing losses from TYLCV. However, they are not available in many of the varieties preferred by growers and are not adapted for all production types (Polston and Lapidot, 2007). Host plant resistance against *B. tabaci*, although promising, is still far from field use and before this RRO will be applicable, substantial applied research will have to be done.

4.4.11. RRO category 11. Options preventing or reducing infestation in the crop – growing plants under exclusion conditions (greenhouse, screen, isolation)

Current situation in the EU This option is not addressed in Council Directive 2000/29/EC.

Comments from Panel Growing *B. tabaci* host plants under exclusion conditions may be highly effective in the management of this pest and its associated viruses both in field and greenhouse grown crops (Hilje et al., 2001; Stansly and Natwick, 2010). In fact, in production areas where *B. tabaci* and its transmitted viruses are endemic, tomato cultivation outside protective structures is almost impossible. Greenhouses may exclude *B. tabaci* with the use of fine mesh netting and young plants grown in open fields can be protected from *B. tabaci* during early development by covered structures. Small tunnels covered with fine mesh can provide protection from *B. tabaci* infestations and virus infections which, especially in the early stages of plant development where tomato is highly susceptible, result in serious reduction of flower and fruit yields (Schuster et al., 1996).

Cultivation of *B. tabaci* hosts under exclusion can be a complement to the requirements for pest-free places of production to increase the efficiency of the applied measures. Effectiveness and feasibility are high with low uncertainty for *B. tabaci* and the viruses it transmits.

4.4.12. RRO category 12. Options preventing or reducing infestation in the crop – harvesting of plants at a certain stage of maturity or during a specified time of year

Current situation in the EU This option is not addressed in Council Directive 2000/29/EC.

Comments from Panel *B. tabaci* and its associated viruses may be present at any vegetative stage of its host plants (Naranjo et al. 2010). *B. tabaci* is present and established in coastal regions of southern Europe (e.g. southern parts of Spain, Italy, Greece) and on islands such as Cyprus and Malta, where it occurs throughout the year. It also may occur throughout the year in northern European countries under protected production conditions, and in those regions with colder winters transient populations may still be present in open fields close to infested protected crops during the summer (Bosco and Caciagli, 1998). Virus infections introduced by *B. tabaci* have most impact when introduced at early stages in plant development thereby reducing flowering and fruit development but also resulting in serious losses because of low fruit quality. Thus, effectiveness and feasibility of this RRO are low, with low uncertainty for *B. tabaci* and the viruses it transmits.

4.4.13. RRO category 13. Options preventing or reducing infestation in the crop – certification scheme

Current situation in the EU this option is not addressed in Council Directive 2000/29/EC.

Comments from Panel Important measures to prevent and reduce whitefly and virus infestation in crops are reliable systems to provide pest- and virus-free planting material. Such systems should be compulsory and subject to inspection and certification. Certification schemes are successfully used in various EU countries. The effectiveness and feasibility of this RRO are high with low uncertainty. An example of certification for nursery production and compulsory measures against *B. tabaci* and virus diseases is provided in the Appendix F.

4.4.14. RRO category 14. Options ensuring that the area remains free from the pest – maintaining Pest Free Area

A pest-free area (PFA) is “an area in which a specific pest does not occur as demonstrated by scientific evidence in which, where appropriate, this condition is being officially maintained (FAO, 1995, ISPM No 4). A pest-free place of production (PFPP) is “a place of production in which a specific pest does not occur as demonstrated by scientific evidence in which, where appropriate, this condition is being officially maintained for a defined period” (FAO, 1999, ISPM No 10). As PFA and PFPP have the same objective and are subject to similar requirements, the Panel merged the information collected for this category. Although PFA and PFPP have the same objective, there is a distinction between how these measures are implemented. A PFA is much larger than a PFPP, includes many PFPPs and may cover whole countries. It is usually maintained for many years and is managed as a whole by the NPPO of the exporting country. A PFPP can maintain its status for one or more growing seasons and is managed individually by the respective producer, under the supervision of the NPPO.

Current situation in the EU With respect to *B. tabaci* and the viruses it transmits, Council Directive 2000/29/EC gives the possibility of import from PFAs and PFPP. Annex IV, Part A, Section II of the Directive deals with the movement of plants and plant products originating inside the community. The concern for *B. tabaci* is connected to its ability to transmit TYLCV. Therefore, if freedom of TYLCV cannot be guaranteed even though no visible symptoms are observed, then *S. lycopersicum* for planting must originate from an area or place of production free from *B. tabaci*, or be treated to ensure freedom of the pest. Part B of Annex IV considers the introduction and movement of certain plant species and plant products (see appendix F) into certain protected zones within the EU (Ireland, UK, Sweden, Finland and parts of Portugal) originating from a PFA or PFPS.

Comments from Panel A PFA is a very efficient measure against the introduction in the RA area of *B. tabaci* and the viruses it transmits. Since official surveillance by the NPPO is implemented to a lesser degree as regards PFPP, the Panel considers that the two options are not equal in their effectiveness. Therefore PFPPs are associated with a higher risk of introduction of *B. tabaci* and the viruses it transmits into the RA area and might require additional measures, e.g. as part of a systems approach.

The measures required for maintenance of PFAs and PFPPs are not clearly specified. Prescribing frequency of inspections and conditions for cropping and treatment would increase the effectiveness of these RROs.

4.4.15. RRO category 15. Options ensuring that the place or site of production or crop is free from the pest – pest free production site

The situation for PFPSs is the same as for RRO Category 14, and has been discussed in Section 4.2.14.

Current situation in the EU Council Directive 2000/29 does not provide options with respect to pest-free production sites (PFPS) with respect to *B. tabaci* and the viruses it transmits.

Comments from Panel The effectiveness of a PFPS is theoretically as high as that of a PFPP or a PFA, but the technical feasibility of maintaining a PFPS on a place of production with infestation of *B. tabaci* and/or viruses it transmits is low. The uncertainty of these ratings is low.

4.4.16. RRO category 16. Options ensuring that the area, place or site of production or crop is free from the pest – inspections, surveillance

Current situation in the EU Annex IV of Directive 2000/29/EC requires the following measures concerning inspection for hosts of *B. tabaci*: (i) inspection prior to export to confirm pest freedom for certain plant species; (ii) inspection at least six times a year for naturally or artificially dwarfed plants for planting; (iii) monitoring to ensure freedom from *B. tabaci* and inspection for symptoms of TYLCV are required for *S. lycopersicum* for planting originating from countries where both pests are known to occur. Monitoring of plants for planting through the complete cycle of vegetation to confirm that no symptoms of *B. tabaci*-transmitted viruses are present is required in countries where *B. tabaci* or other vectors are not known to occur (item 46.a). In case vectors occur in the country of origin, an official statement that no symptoms have been observed during an adequate period is required.

In Annex IV of the Directive 2000/29/EC, additional measures are stipulated for the entry of unrooted cuttings and plants for planting for some plant species (see appendix A). In case the plants do not originate from a PFA, inspection should be carried out throughout the whole production period. When *B. tabaci* has been found at the place of production, it should be subjected to appropriate treatment to ensure pest freedom and weekly official inspections during the whole production period should be carried out, the last one taking place immediately prior to movement.

Comments from Panel Inspections and surveillance are major elements in reducing the phytosanitary risk of entry of harmful organisms in the RA area, and they play an important role in many RRO options. Inspection is evaluated by the Panel under RRO 2 for inspection and testing of consignments. The EU legislation requires treatment and a nine-week surveillance at the place of production to establish freedom of *B. tabaci*, in case the pest has been found during inspection prior to export. During inspection all stages of development of *B. tabaci* can be present and most life stages can easily be found on the crop. Therefore, this is an efficient option to reduce the risk of entry of the pest. Visual inspection for virus symptoms becomes more reliable when older plants are examined because leaf curl symptoms of begomoviruses or leaf yellowing from crinivirus infections often become visible on mature plants. Because of the latency between *B. tabaci* infection and onset of visible symptoms and because symptoms of a number of viruses remain inconspicuous, inspection and surveillance do not guarantee 100 % detection of *B. tabaci*-transmitted viruses.

Prescribing specific methods for surveillance would improve the rate of early establishment of infestations at places for production.

4.4.17. RRO category 17. Options for other types of pathways – natural spread, spread by human activities (people movement, transports, machineries, trade), vectors, phoresy

Current situation in the EU This option is not addressed in Council Directive 2000/29/EC.

Comments from Panel The Panel considered two situations: (i) natural spread of *B. tabaci* within and between countries; and (ii) spread by human activities.

(i) Natural spread of B. tabaci within and between countries As *B. tabaci* immature stages are sessile, except for part of the first nymphal stage during which crawlers may move a few centimetres, movement to other leaves and to neighbouring plants is rare (van Lenteren and Noldus, 1990). *B. tabaci* adults demonstrate two distinct flight patterns: short- and long distance flights (Berlinger, 1986). Short-distance flights of a few metres occur under the plant canopy. Long-distance flights occur when adults take off from a host plant, get caught in an airstream and drift passively. Take-off from a host plant may be initiated when crop conditions deteriorate and/or when whitefly density is very high (van Lenteren and Noldus, 1990). Specific RROs to prevent natural spread of whitefly seem

restricted. It would be best to try to reduce *B. tabaci* populations in crops where it is present. When whitefly populations are low, dispersal will be very limited.

(ii) *Spread of B. tabaci by human activities* The main pathway for spread of *B. tabaci* and the viruses it transmits is by human activities through the trade of plants and plant material. In addition, it is known that travellers may take plant material from one to another country, a largely uncontrolled activity. Importation of plant material infested with (virus infected) *B. tabaci* may occasionally occur. Import of machinery carrying *B. tabaci* and the viruses it transmits from outside the EU seems unlikely and also movement of such machinery over long distances within the EU is not likely.

The only RROs helpful to reduce the risk of import of infested plant material would be Categories 1 and 2, and if these were to be strictly applied, risk of importation or movement of infested plant material within the EU would be limited.

4.4.18. Other relevant information

Not applicable

In the Table 19 the Panel presents a summary of RROs 10-18: prevention, reduction, pest freedom, other pathways and other relevant information.

Table 19: Summary of RROs 10-18: prevention, reduction, pest freedom, other pathways and other relevant information. For more detail on each of the methods mentioned in this table, see the text under RRO category 10-18 in the Appendix F. For a description of the terms used in this table and for the ratings, see Tables 20 - 23 at the end of the section on RROs.

Options for prevention, reduction, pest freedom and other pathways	Effect on <i>Bemisia</i> / uncertainty	Effect on virus/ uncertainty	Applicability	Feasibility
10. Host plant resistance				
Use of <i>Bemisia</i> -resistant cultivars	Major / low	Minor / low	High	High
Use of <i>Bemisia</i> -tolerant cultivars	Minor / low	Minor / low	High	High
Use of virus-resistant cultivars	Minor / low	Massive / low	High	High
Use of virus-tolerant cultivars	Minor / low	Minor / low	High	High
11. Pest exclusion	Major / medium	Major / medium	High	High
12. Harvesting	Minimal / low	Minimal / low	Low	Low
13. Certification	Massive / low	Massive / low	High	High
14. Pest-/virus- free area	Massive / low	Major / low	High	High
15. Pest-/virus- free production site	Major / low	Moderate / low	High	High
16. Pest-/virus- free area by inspection	Major / low	Moderate / low	High	High
17. Other pathways				
Limit natural spread	Minor / high	Minor / high	Low	Low
Limit spread by humans	Moderate / high	Moderate / high	Medium	Low
18. Other information	Not applicable			

4.5. Conclusions on the identification of risk reduction options and evaluation of their effectiveness in reducing the risk to plant health posed by *B. tabaci* and the viruses it transmits

Below, the Panel distinguishes three situations:

- RROs to prevent introduction of non-European populations of *B. tabaci* and the viruses it transmits into the EU,
- RROs to prevent spread of European and non-European populations *B. tabaci* and the viruses it transmits within the EU, and
- RROs for eradication of European and non-European populations of *B. tabaci* and the viruses it transmits

4.5.1. Options to prevent introduction of non-European populations of *B. tabaci* and viruses it transmits into the EU

RRO 1, prohibition of host commodities of the pest, is not feasible for *B. tabaci* and the viruses it transmits because of the large number of commodities that would have to be prohibited to fully exclude their entry. RRO 2, inspection or testing (with low uncertainty, medium applicability and high feasibility), is theoretically an effective option for reducing the risk of entry of both *B. tabaci* and the viruses it transmits, but applicability is limited by the large host plant range of the pest, the difficulty of detecting viruses in host plants with inconspicuous or missing symptoms and the variability in the quality and the frequency of inspections, the expertise of the inspection personnel, the quality of the equipment, etc. (see, for example, European Commission, 2010).

According to the Panel, the best RROs to prevent introduction of *B. tabaci* into the EU are categories 4 and 5 of the options concerning consignments (all with low uncertainty, high applicability and high feasibility), option 13 concerning certification (with low uncertainty, high applicability and high feasibility) and options 14, 15 and 16 concerning pest freedom (all with low uncertainty, high applicability and high feasibility). The other options have a moderate, minor or minimal effect, are characterised by medium or high uncertainty, or are not applicable or feasible.

Option 13, certification, offers the best prevention against introduction of virus-infected plants, including those that are transmitted by *B. tabaci*, provided that effective certification schemes are in place. In addition, option 14, pest freedom, which ensures that the area remains pest and virus free, may offer good prevention against introduction of new viruses, while options 15 and 16 have only moderate effects. RROs affecting consignments (1–8) present only moderate, minor or minimal effectiveness to prevent virus introduction with plants and thus are considered insufficient.

In general, a combination of RROs is required for prevention of introduction of *B. tabaci* and the viruses it transmits, providing a higher level of protection than a single RRO can give. For example, application of RROs 9, 10 and 11 in exporting countries, combined with RROs 1, 2, 4 and 5, related to consignments, and RRO 13, might provide the strongest reduction in introduction.

4.5.1.1. Evaluation of current phytosanitary measures to reduce the probability of introduction of *B. tabaci* and viruses it transmits into the EU

Directive 2000/29/EC lists different RRO combinations/alternatives for different commodities. Most of the options considered by the Panel are included in the Directive 2000/29/EC. Annex IV AI covers hosts of *B. tabaci* and the viruses it transmits. The complex of measures seems efficient for risk reduction, and Council Directive 2000/29/EC theoretically has sufficient provisions to ensure freedom of commodities from *B. tabaci*. However, the technical implementation of the required measures is problematic in those countries where high populations of *B. tabaci* are established outdoors. The large

number of interceptions recorded in some countries is evidence of the difficulty of complying with the Directive.

Annex IVAI of Directive 2000/29/EC gives considerable freedom of choice to the exporter regarding which methods for inspection to use to monitor and assure pest freedom. Even if applied diligently, there are methodical limitations to catch all specimens and to detect all virus infections. Specifying the frequency of inspections, the time periods for surveillance and adequate treatment will improve the effectiveness of the complex of measures.

4.5.1.2. Additional risk reduction options to reduce the probability of introduction of *B. tabaci* and viruses it transmits into the EU identified by the Panel

The Panel has not identified risk reduction options in addition to those targeted for treatment of consignments. However, the numerous interceptions of *B. tabaci* clearly indicate that the legislative requirements should be more stringent in order to better prevent entry of the pest. The Panel suggests several improvements in the current phytosanitary measures to reduce the probability of introduction of *B. tabaci* and the viruses it transmits:

1. The measures required in Annex IVAI for official inspection, pest-free areas and pest-free places of production are not clearly specified. Thus, some measures applied by NPPOs may not be sufficient to eliminate the risk of entry of *B. tabaci* and/or the viruses it transmits. The effectiveness of these measures can be significantly improved through additional requirements for the types of surveys to ensure pest freedom, the methods for official inspection to confirm absence of the pest and the appropriate treatments to eliminate the pest in case of established infestation.
2. The effectiveness of the measures can also be improved by statements of the exporting countries notifying which measures were undertaken to support the official statements confirming that special requirements were implemented.
3. Directive 2000/29/EC does not specify sampling procedures for inspection or testing of consignments. The development of official protocols for sampling of consignments would ensure reliability of the sampling procedures.
4. Cut branches with foliage not intended for planting are not included in the regulations for many host plants of *B. tabaci*, while fruits are not regulated at all. Owing to the risk of entry of TYLCV and *B. tabaci* associated with tomato fruit, the Panel considers that additional requirements for this commodity, such as removal of green parts attached to fruit or issuing of phytosanitary certificates, would effectively minimise the risk of entry of viruliferous *B. tabaci*.

None of the analysed additional RROs on its own would substantially reduce the risk, but they can be combined with the existing measures to improve their effect. The most effective ones would be sanitation before planting and at disposal of crop residues, pest exclusion and regular surveillance.

4.5.2. Options to prevent spread of non-European and European populations of *B. tabaci* and viruses it transmits within the EU

The best RRO to prevent spread of *B. tabaci* with or without viruses within the EU is option 13 concerning certification and options 14, 15 and 16 concerning pest freedom. Additional options which assist in preventing spread are several of the elements mentioned under option 9, control methods (particularly biological control, chemical control and IPM, all with low uncertainty, high applicability and high feasibility), and option 10, host plant resistance (particularly plants resistant to *B. tabaci*, with low uncertainty, high applicability and high feasibility). In addition, RRO 11, the use of greenhouses screenhouses and cages (major effect, medium uncertainty, high applicability and high feasibility) may well assist in preventing spread. Less important are RRO 12, timing of planting and/or harvesting (minimal effect), and RRO 17, prevention of spread by humans other than trade of plant material (moderate effect, high uncertainty, low applicability and low feasibility) and limitation

of natural spread (minor effect, low applicability and low feasibility). However, these options need to be combined with RROs 13–16 to obtain the requested demand of freedom of pest.

Option 10, plants resistant to viruses, and 13, certification, offer the best prevention against spread of viruses with infected plants. Option 14, pest freedom, which ensures that the area remains pest and virus free, may prevent spread of *B. tabaci*-transmitted viruses to other areas in the EU, while options 15 and 16 result in only a moderate effect to prevent their spread.

In general, a combination of RROs will result in better prevention of spread of *B. tabaci* populations and/or the viruses it transmits within the EU than the use of a single RRO. For example, application of elements of RROs 9, 10 and 11 in an IPM programme, together with RROs 13, 14, 15 and 16, might provide the strongest reduction in probability of spread of *B. tabaci* and the viruses it transmits within the EU.

4.5.2.1. Evaluation of current phytosanitary measures

Directive 2000/29/EC lists various RROs in case signs and symptoms of harmful organisms are detected prior to movement of plants and plant products and requires appropriate treatment to ensure pest freedom for certain species of plants for planting which are hosts of *B. tabaci* and the viruses it transmits. Directive 2000/29/EC also makes it possible —under certain conditions—to import plants from PFAs and PFPSs. Further, the Directive considers RROs for the introduction and movement of plants and plant products into certain protected zones within the EU. The currently required measures are efficient for risk reduction and the Directive has enough provisions to ensure freedom of commodities from *B. tabaci* and the viruses it transmits to prevent spread of these harmful organisms within the EU. However, the technical implementation of the required measures does not seem optimal in some countries based on the number of interceptions recorded during the past 20 years.

4.5.2.2. Additional risk reduction options to prevent spread of European and non-European populations of *B. tabaci* within the EU

The Panel has identified several additional risk reduction options targeted at reducing the probability of spread within the EU. An important additional RRO is option 10, the use of plants resistant to *B. tabaci* and/or the viruses it transmits. Also important is RRO 11, the use of greenhouses, screenhouses and cages. Less important additions are RRO 12, timing of planting and/or harvesting (minimal effect), and RRO 17, prevention of spread by humans other than trade of plant material (moderate effect, high uncertainty, low applicability and low feasibility) and limitation of natural spread (minor effect, low applicability and low feasibility). Further, many of the control methods listed under RRO 9 are not specifically mentioned in the current Council Directive 2000/29/EC and there might be new elements listed by the Panel.

4.5.3. Options to eradicate non-European and European populations of *B. tabaci* and viruses it transmits

Once *B. tabaci* and viruses it transmits have entered the EU including PZ, adequate measures identified by the special EPPO standard on disinfection can be applied for eradication of *B. tabaci* (EPPO, 2009a). The Panel did not identify additional measures.

However, eradication of *B. tabaci* is not always possible and eradication of its viruses may be impossible. However, a number of RROs are available to reduce the impact of *B. tabaci* and its viruses. Option 9, control methods, offers most RROs and a combination of biological control, chemical control and IPM elements including crop-free periods, sanitation before planting, disposal of crop residues and scouting can considerably contribute to reduction of *B. tabaci* populations and its viruses. Furthermore, options 10 (host plant resistance), 11 (greenhouses, screenhouses and cages) and 13 (certification of planting material) provide important measures to reduce or eliminate negative effects of the pest and the viruses it transmits. A combination of RROs will result in reduction of infestation of *B. tabaci* and the viruses it transmits. RROs 9, 10 and 11 as elements of an IPM

programme efficiently reduce population density of *B. tabaci*, thereby reducing spread of viruses and crop losses from disease.

4.6. Final conclusions on the risk reduction options

According to the background as provided by the European Commission, *B. tabaci* is a regulated harmful organism in the EU. Its regulation makes a distinction between non-European and European populations.

Non-European *B. tabaci* populations are listed in Annex 1, Part A, Section I, of Council Directive 2000/29/EC as “harmful organisms whose introduction into, and spread within, all Member States shall be banned”. Annex IV, Part A, Section I, lists specific import requirements for herbaceous plants for planting and several species of cut flowers and leafy vegetables in connection with non-European *B. tabaci* populations.

The Panel concludes that the current phytosanitary measures mentioned in Council Directive 2000/29/EC provide sufficient options to ensure freedom of commodities from *B. tabaci* to prevent entry and spread into the EU. However, the number of interceptions provides evidence that implementation of appropriate measures does not entirely prevent to entry of the pest. While further risk reduction options in addition to those targeted at treatment of consignments were not identified, improvements concerning the requirements formulated in the Council Directive can be suggested:

1. Considering the broad spectrum of plant species on which *B. tabaci* is intercepted, a specific mention of the woody plant species *Ficus* L. and *Hibiscus* L. is no longer warranted. The list of plants specified in Annex IV, Part A, 45.1 could be extended to plants for planting in general - herbaceous and woody plants – and disregarding their status as host plants for *B. tabaci*. This then covers the long list of plants on which *B. tabaci* can be found and is especially useful when herbaceous and woody plant species cannot be unequivocally be distinguished.
2. Similarly, the list of cut flowers (Annex IV 45.2.) could also be extended to cover the diversity of plant species imported as cut flowers.
3. The list of viruses in Annex IV 46 should be revised and updated also with reference to the EPPO Alert list A1 and A2 in which for e.g. Cowpea mild mottle virus is no longer listed. The relevant harmful viruses transmitted by *B. tabaci* can also include a statement of the genera to which those viruses belong.
4. In Annex IV 45.3 the statement concerning absence of tomato yellow leaf curl virus symptoms could be amended to include all *B. tabaci* transmitted virus species that cause tomato yellow leaf curl disease and which are currently not present in Europe.
5. In Annex IV Part B, 24.1- 24.3 While it is clear that cuttings and plants of *Euphorbia pulcherrima* comprise the largest volume of trade in the EU, similarly to point 1, there is no argument why the requirements for freedom from *B. tabaci* should be limited only to *E. pulcherrima*, *Begonia* or other plant species listed in 24.1- 24.3. This list should/could therefore be amended.
6. Drafting of specifications for generic measures required in Annex IVAI for official inspection, pest free areas and pest free places of production.
7. The action mentioned under point 1 could be supported by asking exporting countries to provide detailed descriptions of the particular measures implemented following the specifications.
8. Development of official protocols for sampling of consignments to specify the sampling procedures, confidence levels, etc.

9. Considering additional requirements for import of tomato fruit such as removal of green parts attached to fruit or issuing of phytosanitary certificates, due to the significant risk of entry of viruses causing tomato yellow leaf curl disease and *B. tabaci* associated with this commodity.

European *B. tabaci* populations are listed in Annex I, Part B, as “harmful organisms whose introduction into, and spread within, certain protected zones shall be banned”. Annex IV, Part A, Section II, and Part B, outlines specific requirements for the internal movement of certain plants in connection with *B. tabaci* and the viruses it transmits. The Panel concludes that the current phytosanitary measures mentioned in Council Directive 2000/29/EC theoretically provide sufficient options to ensure freedom of commodities from *B. tabaci* and the viruses it transmits to prevent spread within the EU, and, in particular, maintaining pest-free areas seems appropriate to achieve this goal. However, implementation of the required measures is not sufficient in some countries/areas, which can be concluded from the number of interceptions from trade within the EU (74 % of all records are on plants for planting). The Panel has identified several additional methods to limit or prevent spread within the EU of *B. tabaci* and the viruses it transmits. Those concern:

1. the use of host plant resistance to *B. tabaci* and/or its viruses,
2. the use of greenhouses, screenhouses and cages, and
3. the use of control methods summarised by the Panel which are not specifically mentioned in the current Council Directive 2000/29/EC (these methods might constitute important new elements for managing *B. tabaci* and its viruses).

The Panel has not identified additional risk reduction options for eradication of *B. tabaci* and the viruses it transmits, although application of several of the many control methods for treatment of the crop, field or place of production will result in a reduction in density of *B. tabaci* populations and a reduced transmission and spread of viruses, with a subsequent lower impact on crops.

Finally, the Panel concludes that there are many effective risk reduction options available to prevent introduction and establishment of *B. tabaci* and the viruses it transmits into the EU, and to prevent spread of *B. tabaci* within the EU. The Panel stresses that only the combination of risk reduction options and the consequent pursuit of a comprehensive crop management regime will result in sustainable management of *B. tabaci* and the viruses it transmits.

Description of terms used in the tables with overviews and evaluation of risk reduction options

Definitions

- Effect of a risk reduction option: Capability of an option to reduce the risk caused by a harmful organism.
- Applicability: can the method be applied for this crop / cropping situation?
- Feasibility: is it expected that the method will be applied (e.g. a method can be very well applied, but is so expensive that the feasibility of application is minimal)?

Table 20: Ratings for effectiveness of risk reduction options

Rating	Descriptors
<i>Minimal</i>	The risk reduction option has no practical effect in reducing the probability of entry or establishment or spread, or the potential consequences
<i>Minor</i>	The risk reduction option reduces, to a limited extent, the probability of entry or establishment or spread, or the potential consequences

<i>Moderate</i>	The risk reduction option reduces, to a substantial extent, the probability of entry or establishment or spread, or the potential consequences
<i>Major</i>	The risk reduction option reduces the probability of entry or establishment or spread, or the potential consequences, by a major extent
<i>Massive</i>	The risk reduction option essentially eliminates the probability of entry or establishment or spread, or any potential consequences

Table 21: Ratings for uncertainty used in the section risk reduction options

Rating	Descriptors
<i>Low</i>	No or little information is missing or no or few data are missing, incomplete, inconsistent or conflicting. No subjective judgment is introduced. No unpublished data are used
<i>Medium</i>	Some information is missing or some data are missing, incomplete, inconsistent or conflicting. Subjective judgments are introduced with supporting evidence. Unpublished data are sometimes used
<i>High</i>	Most information is missing or most data are missing, incomplete, inconsistent or conflicting. Subjective judgment may be introduced without supporting evidence. Unpublished data are frequently used

Table 22: Ratings for the applicability of risk reduction options

Rating	Descriptors
<i>Low</i>	The risk reduction option can hardly ever be applied
<i>Medium</i>	The risk reduction option can be applied in some situations
<i>High</i>	The risk reduction option can often be applied

Table 23: Ratings for the feasibility of risk reduction options

Rating	Descriptors
<i>Low</i>	The feasibility of application of this risk reduction option is minimal
<i>Medium</i>	The feasibility of application of this risk reduction option is moderate
<i>High</i>	The feasibility of application of this risk reduction option is maximal

CONCLUSIONS

After consideration of the evidence, the Panel reached the following conclusions:

With regard to the assessment of the risks to plant health:

B. tabaci is considered to be one of the most serious threats to crop cultivation worldwide, predominantly because of the large number of viruses it transmits. In regions where *B. tabaci* is established, viruses transmitted by this insect, especially those affecting tomato and cucurbits and also beans, pepper and aubergines, are responsible for severe diseases that have a strong negative impact on crop yield. As a consequence, crop production in those areas is not possible without a system wide and comprehensive set of pest and disease management measures in place. In the RA area, *B. tabaci* is present outdoors in coastal areas with a Mediterranean climate, and in many EU countries the pest is present in greenhouses.

B. tabaci is a complex of at least 28 indistinguishable morphocryptic species of which four occur in Europe. Two species, Mediterranean (Med, formerly referred to as Q-biotype) and Middle East-Asia Minor 1 (MEAM1, formerly referred to as B-biotype) are mostly associated with negative effects on crops such as ornamentals, tomato and cucurbits, and are prevalent both in Europe and in many regions across the world. Many other *B. tabaci* species exist outside the risk assessment area, and those can reach high population densities, but it is only Med and MEAM1 that are considered invasive. All *B. tabaci* species can transmit viruses, and the viruses associated with *B. tabaci* reported from around the world have an immense diversity, which is reflected in numerous species and strains. In general, diseases resulting from virus infections have a serious negative impact on crops and, thus, the introduction of *B. tabaci* -transmitted viruses currently not present in the EU would be a significant risk.

ENTRY

For entry of *B. tabaci* and the viruses it transmits, five pathways have been identified, and the most relevant one is the plants for planting pathway. Plants not intended for planting (cut flowers and branches with foliage) and the pathway represented by fruits and vegetables were also considered, while entry of *B. tabaci* through human-associated means not involving plants (e.g. on vehicles or clothes) and entry of insects by natural means (e.g. with wind or active flight) were considered negligible pathways and not assessed in this opinion.

Viruses can enter with infected plant material and with insects carrying the viruses (viruliferous insects). The transmission modes of *B. tabaci* -transmitted viruses are substantially different and have a strong influence on the probability of entry. Therefore, viruses were grouped into circulative transmitted viruses (begomoviruses) and non-circulative viruses (all other viruses); these two groups are considered separately in the opinion.

The evaluation of the likelihood of entry of pest and viruses was supported with a probabilistic model that combined expert assessment of the presumed risk of entry from the major world areas with trade volumes of commodities related to the three pathways.

Pathway 1. Plants for planting

- Entry of *B. tabaci* can be expected from all world areas where populations of this insect are established, because *B. tabaci* is not only a polyphagous pest infesting a wide range of plant species (host plants) but can also be carried along on non-hosts, that is with plants on which the insect is only visiting or probing (non-host plants).
- The probability of entry of *B. tabaci* into the European Union with the plants for planting pathway is rated as likely, because of the frequent association of insects with the pathway at origin and based on the number of interception records despite strict phytosanitary requirements for places of production of plants for planting. Although the fraction of

intercepted consignments relative to the total number of consignments imported into the EU is low, the high trade volumes justify this rating.

- The major volume of trade in this pathway mainly concerns ornamental plants. The specific ornamental plant species that are imported via this pathway are non-host plants for *B. tabaci* -transmitted viruses. Entry of circulatively transmitted viruses can occur with viruliferous *B. tabaci* insects and with infected plants while non-circulatively transmitted viruses can enter only with infected host plants, because of their limited persistence in their vector. Entry of viruses with viruliferous *B. tabaci* or with infected crop plants is considered as moderately likely.

Pathway 2. Cut flowers and branches with foliage

- The probability of entry of *B. tabaci* into the EU with the pathway of cut flowers and branches with foliage is considered as moderately likely because eggs and nymphal stages of the pest can survive transport. The short storage periods and limited vase life of cut flowers reduces the probability of transfer of insects to a suitable host plant. Although the most important cut flower species require phytosanitary inspection and a phytosanitary certificate for import, interceptions still occurs and the high volume of trade justifies this rating.
- The entry of circulatively transmitted viruses is bound to viruliferous *B. tabaci* adults. Because survival of adult insects during transport and storage is unlikely, the probability that viruses enter via this pathway is considered unlikely. The probability that non-circulatively transmitted viruses associated with *B. tabaci* enter into the EU with cut flowers is rated as very unlikely as the ornamentals under concern are non-host plants for these viruses.

Pathway 3. Fruits and vegetables including leafy herbs for consumption

- The probability of entry of *B. tabaci* into the EU with the pathway fruits and vegetables is estimated as unlikely. These commodities intended for consumption are unlikely to present a pathway because of the pathway characteristics (cold chain) and the low probability of transfer to a suitable host after arrival in the EU. This is despite the numbers of specimens intercepted on commodities entering the EU. Because leafy herbs imported as live potted plants can have a prolonged vase life, a higher risk is associated with these cases and thus the probability of entry of *B. tabaci* would be moderately likely.
- Insects may enter the RA area on vegetables, leafy herbs (specific regulations apply only for *Ocimum* spp. and *Apium* spp.) and on fruits with remaining leaves (e.g. tomato vines).
- Virus entry with *B. tabaci* on fruits, vegetables and leafy herbs is considered very unlikely, because many species used as leafy vegetables and herbs (basil) are not susceptible to *B. tabaci*-transmitted viruses. There also is a very low probability that transfer from virus-infected fruits to suitable host plants would occur. Notwithstanding this, in regions where *B. tabaci* is established outdoors, discarded fruits or peels can be sources of infections and pathways of virus entry.

Information on *B. tabaci* interceptions shows that control measures and phytosanitary requirements in the area of production and inspections to prevent insects from entry have limitations. The limited efficacy of inspections at entry and the high volumes of trade attribute a medium uncertainty to the evaluation of the risk of entry of *B. tabaci*. Uncertainty further exists about aquatic plants entering the EU, on which *B. tabaci* is frequently intercepted. The lack of information on their final use in the EU contributes to uncertainty. Because of dual use, some commodities can be assigned either to pathway 2 or to pathway 3. In the case of some species, e.g. *Eryngium* sp. and *Limnophila aromatica*, high rates of interception were in the past, observed on cut flowers, but currently these generate interception reports almost exclusively on vegetables and fruit for consumption. Because cut flowers and branches with foliage are subject to more stringent import requirements and fruits and vegetables for

consumption are largely not regulated, such changes in the commodity class further contribute to uncertainties on the ratings of the entry pathways for *B. tabaci*.

For viruses transmitted by *B. tabaci*, uncertainty exists whether newly introduced ornamental plant species including aquatic plants can be new host plants for hitherto unknown viruses. However, the uncertainties concerning new viruses entering into the EU with any of the pathways can be rated as low.

The application of measures for import consignments which pose a risk seems to be most effective to reduce the probability of entry with all major entry pathways for *B. tabaci*. However, interception reports indicate the limitations of the measures.

ESTABLISHMENT

B. tabaci species MEAM1 and Med are established in many parts of the risk assessment area. As there are many host plant species available for these polyphagous pests, outdoor establishment is limited only by climatic conditions. The assessment of *B. tabaci* establishment is supported by the results of a population dynamics model that was developed with biodemographic temperature-dependent functions estimated for *B. tabaci* in which climate data were used to predict the area of potential establishment of the insect and the viruses it transmits in Europe.

- Assuming similar climatic requirements for all *B. tabaci* species, outdoor establishment of *B. tabaci* including those species entering the risk assessment area from outside is considered as likely in the areas where *B. tabaci* is already present. Similarly, the climatic conditions for crop production in greenhouses favour *B. tabaci* population development and, as proven by records of outbreaks in greenhouses, *B. tabaci*, once introduced, is likely to establish.
- In crops such as tomato or cucurbits, Med and MEAM1 are well adapted to the intensive production conditions, and newly invading *B. tabaci* species would probably be less competitive in those crops, but may establish on other plant species. Because *B. tabaci* Med and MEAM1 are highly invasive species and are present throughout the world, it is likely that insects entering into the EU are MEAM1 and Med, and those would merge with existing populations of the same species.

In Europe, several *B. tabaci*-transmitted viruses are present in regions where the insect is established outdoors. Those causing tomato yellow leaf curl disease (TYLCD) are considered among the most serious plant viruses in crops.

- Because of the availability of suitable host plants and the presence of efficient vectors, viruses transmitted by *B. tabaci* are likely to establish. This assessment concerns viruses infecting tomato and cucurbit crops, which are available almost throughout the year in the production areas of the Mediterranean regions (greenhouses and outdoors) and in the greenhouses of northern EU countries.
- New diseases from recently emerging (novel) *B. tabaci*-transmitted viruses mostly recorded on cucurbits and on tomato provide evidence for newly introduced pathogens and indicate ongoing processes of establishment.
- As far as establishment of other *B. tabaci*-transmitted viruses is concerned, their establishment largely depends on suitable host plants being available in the environment and serving as reservoirs for survival and new plant infections. The availability of alternative host plants is not an important requirement for viruses infecting tomatoes and cucurbits.
- Newly introduced begomoviruses infecting tomato would likely contribute to TYLCD, establish mixed virus infections, or compete with existing Tomato yellow leaf curl viruses (TYLCV) that are highly adapted to tomato.

Uncertainties concerning the assessment of the outdoors establishment of *B. tabaci* are rated as low, because, according to the population dynamic model, estimates of the area of supposed establishment

and the northern limits of expansion can be well defined. *B. tabaci*-transmitted viruses are established outdoors in several EU Member States. Uncertainties concerning the establishment of *B. tabaci* in greenhouses are also rated as low because of controlled climatic conditions favouring population development and growth of this insect.

The uncertainty rating for the establishment of newly introduced viruses, however, is considered as medium because of the limited knowledge about factors driving the epidemics of NVs.

SPREAD

Spread of *B. tabaci* in the risk assessment area mainly depends on climatic conditions and the intensity of trade between EU countries. Long-distance spread is mostly by transport of *B. tabaci* with plant commodities through trade, which also contributes to dissemination of viruses. Spread is rated as moderately likely for *B. tabaci* and the viruses it transmits.

- An expansion of the outdoor area currently invaded by *B. tabaci*, as well as an increase in its population density, is expected only if the average temperatures in Europe increase. However, even considering a climate change scenario with an increase of on average +2 °C, the northern most limit of distribution of *B. tabaci* will expand, but the insect will still not establish outdoors in northern EU countries, including those with protected zone status.
- In the Mediterranean coastal regions, the ample availability of host plants and suitable environmental conditions support the spread of *B. tabaci* and its viruses. Because of the application of control measures, the population densities of *B. tabaci* are kept low, which also results in a lower incidence of virus diseases.
- Spread of *B. tabaci* and its viruses to northern EU countries occurs because of the high volume of inter-EU trade and insufficient measures to prevent spread.

Uncertainties concerning the spread of *B. tabaci* are rated low because the climate factors limiting outdoor expansion are well known and the northern limits of expansion can be well defined. Medium uncertainty is associated with the rating for virus spread because of the paucity of information on factors driving the epidemics of newly introduced viruses and whether new viruses would express biological features resulting in enhanced vector transmission, rate of replication or host range.

Although there are many effective control options available for *B. tabaci* that also reduce virus problems, they cannot prevent establishment and spread of newly arriving *B. tabaci* and its viruses. Application of control measures can reduce but not eliminate the probability of spread.

IMPACT

Serious crop diseases are the consequence of infections with viruses transmitted by *B. tabaci* and major consequences for crop production are a result of this whitefly spreading the diseases. Appropriate protection measures need to be in place to limit yield losses, and this also includes crops not affected by viruses transmitted by *B. tabaci* (ornamentals) but on which insect populations can develop rapidly. Because new types of diseases can be expected from novel viruses and also because begomoviruses evolve rapidly, frequently undergo recombination and also occur as mixed infections, the introduction of viruses can be associated with more severe disease symptoms. The overall assessment of the consequences and damage is affected only by the uncertainty on additional consequences from the introduction, establishment and spread of both *B. tabaci* and the viruses it transmits hitherto not present in the risk assessment area. This assessment is associated with a medium level of uncertainty.

The Panel considers that *B. tabaci* and the diseases from viruses transmitted by this insect primarily affect the yield and quality of crops. The Panel is not aware of publications demonstrating serious pest or disease effects on wild plants in cultivated or natural environments. The most commonly expected environmental effects are those resulting from inappropriate pesticide applications. Environmental

side-effects are considered to be negligible with low uncertainty in the current area of distribution and in the risk assessment area.

With regard to risk reduction options:

According to the background as provided by the European Commission, *B. tabaci* is a regulated harmful organism in the EU. Its regulation makes a distinction between non-European and European populations.

Non-European *B. tabaci* populations are listed in Annex 1, Part A, Section I, of Council Directive 2000/29/EC as “harmful organisms whose introduction into, and spread within, all Member States shall be banned”. Annex IV, Part A, Section I, lists specific import requirements for herbaceous plants for planting and several species of cut flowers and leafy vegetables in connection with non-European *B. tabaci* populations.

The Panel concludes that the current phytosanitary measures mentioned in Council Directive 2000/29/EC provide sufficient options to ensure freedom of commodities from *B. tabaci* to prevent its entry and spread into the EU. However, the number of interceptions provides evidence that implementation of appropriate measures does not entirely prevent the entry of the pest. While further risk reduction options in addition to those targeted at treatment of consignments were not identified, improvements concerning the requirements formulated in the Council Directive can be suggested:

1. Considering the broad spectrum of plant species on which *B. tabaci* is intercepted, a specific mention of the woody plant species *Ficus* L. and *Hibiscus* L. is no longer warranted. The list of plants specified in Annex IV, Part A, 45.1 could be extended to plants for planting in general - herbaceous and woody plants – and disregarding their status as host plants for *B. tabaci*. This then covers the long list of plants on which *B. tabaci* can be found and is especially useful when herbaceous and woody plant species cannot be unequivocally be distinguished.
2. Similarly, the list of cut flowers (Annex IV 45.2.) could also be extended to cover the diversity of plant species imported as cut flowers.
3. The list of viruses in Annex IV 46 should be revised and updated also with reference to the EPPO Alert list A1 and A2 in which for e.g. Cowpea mild mottle virus is no longer listed. The relevant harmful viruses transmitted by *B. tabaci* can also include a statement of the genera to which those viruses belong.
4. In Annex IV 45.3 the statement concerning absence of tomato yellow leaf curl virus symptoms could be amended to include all *B. tabaci* transmitted virus species that cause tomato yellow leaf curl disease and which are currently not present in Europe.
5. In Annex IV Part B, 24.1- 24.3 While it is clear that cuttings and plants of *Euphorbia pulcherrima* comprise the largest volume of trade in the EU, similarly to point 1, there is no argument why the requirements for freedom from *B. tabaci* should be limited only to *E. pulcherrima*, *Begonia* or other plant species listed in 24.1- 24.3. This list should/could therefore be amended.
6. Drafting of specifications for generic measures required in Annex IVAI for official inspection, pest free areas and pest free places of production.
7. The action mentioned under point 1 could be supported by asking exporting countries to provide detailed descriptions of the particular measures implemented following the specifications.
8. Development of official protocols for sampling of consignments to specify the sampling procedures, confidence levels, etc.

9. Considering additional requirements for import of tomato fruit such as removal of green parts attached to fruit or issuing of phytosanitary certificates, due to the significant risk of entry of viruses causing tomato yellow leaf curl disease and *B. tabaci* associated with this commodity.

European *B. tabaci* populations are listed in Annex I, Part B, as “harmful organisms whose introduction into, and spread within, certain protected zones shall be banned”. Annex IV, Parts A and B, outlines specific requirements for the internal movement of certain plants in connection with *B. tabaci* and the viruses it transmits. The Panel concludes that the current phytosanitary measures mentioned in Council Directive 2000/29/EC theoretically provide sufficient options to ensure freedom of commodities from *B. tabaci* and the viruses it transmits to prevent spread within the EU and, in particular, that maintaining pest-free areas seems appropriate to achieve this goal. However, implementation of the required measures is not sufficient in some countries/areas, which can be concluded from the number of interceptions from trade within the EU (74 % of all records are on plants for planting). The Panel has identified several additional methods to limit or prevent spread within the EU of *B. tabaci* and the viruses it transmits. Those concern:

1. the use of host plant resistance to *B. tabaci* and/or its viruses,
2. the use of greenhouses, screenhouses and cages, and
3. the use of control methods summarised by the panel which are not specifically mentioned in the current Council Directive 2000/29/EC (these methods might constitute important new elements for managing *B. tabaci* and its viruses).

The Panel has not identified additional risk reduction options for the eradication of *B. tabaci* and the viruses it transmits, although application of several of the many control methods for treatment of the crop, field or place of production will result in a reduction in density of *B. tabaci* populations and a reduced transmission and spread of viruses, with a subsequent lower impact on crops.

Finally, the Panel concludes that there are many effective risk reduction options available to prevent the introduction and establishment of *B. tabaci* and the viruses it transmits into the EU, and to prevent the spread of *B. tabaci* within the EU. The Panel stresses that only the combination of risk reduction options and the consequent pursuit of a comprehensive crop management regime will result in the sustainable management of *B. tabaci* and the viruses it transmits.

DOCUMENTATION PROVIDED TO EFSA

1. Request (Background and terms of reference) to provide a scientific opinion on the risk to plant health of *Bemisia tabaci* for the EU territory. SANCO.E2 GCIap (201 1) 1104271, 24 October 2011. Submitted by European Commission, DG SANCO Health and Consumers Directorate Directorate-General.
2. Israel’s opinion on the risks posed by *Bemisia tabaci*. 17 May 2012. Submitted by European Commission, DG SANCO Health and Consumers Directorate Directorate-General.

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A. COUNCIL DIRECTIVE 2000/29/EC, SPECIAL REQUIREMENTS FOR *BEMISIA TABACI*

Table A.1: Council Directive 2000/ 29/ EC, special requirements for *B. tabaci* as specified in Annex IV, Part A, Section I

ANNEX IV, PART A		
SPECIAL REQUIREMENTS WHICH MUST BE LAID DOWN BY ALL MEMBER STATES FOR THE INTRODUCTION AND MOVEMENT OF PLANTS, PLANT PRODUCTS AND OTHER OBJECTS INTO AND WITHIN ALL MEMBER STATES		
Section I		
PLANTS, PLANT PRODUCTS AND OTHER OBJECTS ORIGINATING OUTSIDE THE COMMUNITY		
	Plants, plant products and other objects	Special requirements
45.1.	Plants of herbaceous species and plants of <i>Ficus</i> L. and <i>Hibiscus</i> L., intended for planting, other than bulbs, corms, rhizomes, seeds and tubers, originating in non-European countries	<p>Without prejudice to the requirements applicable to the plants in Annex IV, Part A, Section I(27.1), (27.2), (28), (29), (32.1), (32.3) and (36.1), official statement that the plants:</p> <p>(a) originate in an area, established in the country of export by the national plant protection service in that country, as being free from <i>Bemisia tabaci</i> Genn. (non-European populations) in accordance with relevant International Standards for Phytosanitary Measures, and which is mentioned on the certificates referred to in Articles 7 or 8 of this Directive under the rubric 'Additional declaration',</p> <p>or</p> <p>(b) originate in a place of production, established in the country of export by the national plant protection service in that country, as being free from <i>Bemisia tabaci</i> Genn. (non-European populations) in accordance with relevant International Standards for Phytosanitary Measures, and which is mentioned on the certificates referred to in Articles 7 or 8 of this Directive under the rubric 'Additional declaration', and declared free from <i>Bemisia tabaci</i> Genn. (non-European populations) on official inspections carried out at least once each three weeks during the nine weeks prior to export,</p> <p>or</p> <p>(c) in cases where <i>Bemisia tabaci</i> Genn. (non-European populations) has been found at the place of production, are held or produced in this place of production and have undergone an appropriate treatment to ensure freedom from <i>Bemisia tabaci</i> Genn. (non-European populations) and subsequently this place of production shall have been found free from <i>Bemisia tabaci</i> Genn. (non-European populations) as a consequence of the implementation of appropriate procedures aiming at eradicating <i>Bemisia tabaci</i> Genn. (non-European populations), in both official inspections carried out weekly during the nine weeks prior to export and in monitoring procedures throughout the said period. Details of the treatment shall be mentioned on the certificates referred to in Article 7 or 8 of this Directive.</p>
45.2.	Cut flowers of <i>Aster</i> spp., <i>Eryngium</i> L., <i>Gypsophila</i> L., <i>Hypericum</i> L., <i>Lisianthus</i> L., <i>Rosa</i> L., <i>Solidago</i> L., <i>Trachelium</i> L., and leafy vegetables of <i>Ocimum</i> L., originating in non-European countries	<p>Official statement that the cut flowers and leafy vegetables:</p> <p>— originate in a country free from <i>Bemisia tabaci</i> Genn. (non-European populations),</p> <p>or</p> <p>— immediately prior to their export, have been officially inspected and found free from <i>Bemisia tabaci</i> Genn. (non-European populations).</p>
45.3.	Plants of <i>Lycopersicon lycopersicum</i> (L.) Karsten ex Farw. intended for planting, other than seeds, originating in countries where Tomato yellow leaf curl virus is known to occur	Without prejudice to the requirements applicable to plants listed in Annex III(A)(13) and Annex IV(A)(I)(25.5), (25.6) and 25.7 where appropriate
	(a) Where <i>Bemisia tabaci</i> Genn. is not known to occur	Official statement that no symptoms of Tomato yellow leaf curl virus have been observed on the plants

	<p>(b) Where <i>Bemisia tabaci</i> Genn. is known to occur</p>	<p>Official statement that:</p> <p>(a) no symptoms of Tomato yellow leaf curlvirus have been observed on the plants,</p> <p>and</p> <p>(aa) the plants originate in areas known to be free from <i>Bemisia tabaci</i> Genn., or</p> <p>(bb) the place of production has been found free from <i>Bemisia tabaci</i> Genn. on official inspections carried out at least monthly during the three months prior to export;</p> <p>or</p> <p>(b) no symptoms of Tomato yellow leaf curl virus have been observed on the place of production and the place of production has been subjected to an appropriate treatment and monitoring regime to ensure freedom from <i>Bemisia tabaci</i> Genn.</p>
<p>46.</p>	<p>Plants intended for planting, other than seeds, bulbs, tubers, corms and rhizomes, originating in countries where the relevant harmful organisms are known to occur. ◀</p> <p>The relevant harmful organisms are:</p> <ul style="list-style-type: none"> — Bean golden mosaic virus, — Cowpea mild mottle virus, — Lettuce infectious yellow virus, — Pepper mild tigré virus, — Squash leaf curl virus, — other viruses transmitted by <i>Bemisia tabaci</i> Genn. <p>(a) Where <i>Bemisia tabaci</i> Genn. (non-European populations) or other vectors of the relevant harmful organisms are not known to occur</p> <p>(b) Where <i>Bemisia tabaci</i> Genn. (non-European populations) or other vectors of the relevant harmful organisms are known to occur</p>	<p>Without prejudice to the requirements applicable to the plants listed in Annex III (A)(13) and Annex IV(A)(I)(25.5) (25.6), (32.1), (32.2), (32.3), (35.1), (35.2), (44), ►M22 _____ ◀ (45.1) ►M3 , (45.2) and (45.3) ◀ where appropriate</p> <p>Official statement that no symptoms of the relevant harmful organisms have been observed on the plants during their complete cycle of vegetation</p> <p>Official statement that no symptoms of the relevant harmful organisms have been observed on the plants during an adequate period,</p> <p>and</p> <p>(a) the plants originate in areas known to be free from <i>Bemisia tabaci</i> Genn. and other vectors of the relevant harmful organisms;</p> <p>or</p> <p>(b) the place of production has been found free from <i>Bemisia tabaci</i> Genn. and other vectors of the relevant harmful organisms on official inspections carried out at appropriate times;</p> <p>or</p> <p>(c) the plants have been subjected to an appropriate treatment aimed at eradicating <i>Bemisia tabaci</i> Genn.</p>

Table A.2: Council Directive 2000/ 29/ EC, special requirements *B. tabaci* as specified in Annex IV, Part A, Section II

ANNEX IV, PART A		
SPECIAL REQUIREMENTS WHICH MUST BE LAID DOWN BY ALL MEMBER STATES FOR THE INTRODUCTION AND MOVEMENT OF PLANTS, PLANT PRODUCTS AND OTHER OBJECTS INTO AND WITHIN ALL MEMBER STATES		
Section II		
PLANTS, PLANT PRODUCTS AND OTHER OBJECTS ORIGINATING IN THE COMMUNITY		
	Plants, plant products and other objects	Special requirements
26.1	Plants of <i>Lycopersicon lycopersicum</i> (L.) Karsten ex Farw., intended for planting, other than seeds	Without prejudice to the requirements applicable to the plants, where appropriate, listed in Annex IV(a)(II)(18.6) and (23) official statement that: (a) the plants originate in areas known to be free from Tomato yellow leaf curl virus; or (b) no symptoms of Tomato yellow leaf curl virus have been observed on the plants; and (aa) the plants originate in areas known to be free from <i>Bemisia tabaci</i> Genn; or (bb) the place of production has been found free from <i>Bemisia tabaci</i> Genn. on official inspections carried out at least monthly during the three months prior to export; or (c) no symptoms of Tomato yellow leaf curl virus have been observed on the place of production and the place of production has been subjected to an appropriate treatment and monitoring regime to ensure freedom from <i>Bemisia tabaci</i> Genn.

Table A.3: Council Directive 2000/ 29/ EC, special requirements *B. tabaci* as specified in Annex IV, Part B

ANNEX IV, PART B			
SPECIAL REQUIREMENTS WHICH SHALL BE LAID DOWN BY ALL MEMBER STATES FOR THE INTRODUCTION AND MOVEMENT OF PLANTS, PLANT PRODUCTS AND OTHER OBJECTS INTO AND WITHIN CERTAIN PROTECTED ZONES			
	Plants, plant products and other objects	Special requirements	Protected zone(s)
24.1	Unrooted cuttings of <i>Euphorbia pulcherrima</i> Willd., intended for planting	Without prejudice to the requirements applicable to the plants listed in Annex IV(A)(I)(45.1), where appropriate, official statement that: (a) the unrooted cuttings originate in an area known to be free from <i>Bemisia tabaci</i> Genn. (European populations), or (b) no signs of <i>Bemisia tabaci</i> Genn. (European populations) have been observed either on the cuttings or on the plants from which the cuttings are derived and held or produced at the place of production on official inspections carried out at least each three weeks during the whole production period of these plants on this place of production,	IRL, P (►M17 Azores, Beira Interior, Beira Litoral, Entre Douro e Minho, Madeira, Ribatejo e Oeste (communes of Alcobaca, Alenquer, Bombarral, Cadaval, Caldas da Rainha, Lourinhã, Nazaré, Obidos, Peniche and Torres Vedras) and Trás-os-Montes ◀), FI, S, UK

		<p>or</p> <p>(c) in cases where <i>Bemisia tabaci</i> Genn. (European populations) has been found at the place of production, the cuttings and the plants from which the cuttings are derived and held or produced in this place of production have undergone an appropriate treatment to ensure freedom from <i>Bemisia tabaci</i> Genn. (European populations) and subsequently this place of production shall have been found free from <i>Bemisia tabaci</i> Genn. (European populations) as a consequence of the implementation of appropriate procedures aiming at eradicating <i>Bemisia tabaci</i> Genn. (European populations), in both official inspections carried out weekly during the three weeks prior to the movement from this place of production and in monitoring procedures throughout the said period. The last inspection of the above weekly inspections shall be carried out immediately prior to the above movement</p>	
24.2	<p>Plants of <i>Euphorbia pulcherrima</i> Willd., intended for planting, other than:</p> <ul style="list-style-type: none"> — seeds, — those for which there shall be evidence by their packing or their flower (or bract) development or by other means that they are intended for sale to final consumers not involved in professional plant production, — those specified in 24.1 	<p>Without prejudice to the requirements applicable to the plants listed in Annex IV(A)(I)(45.1), where appropriate official statement that:</p> <p>(a) the plants originate in an area known to be free from <i>Bemisia tabaci</i> Genn. (European populations),</p> <p>or</p> <p>(b) no signs of <i>Bemisia tabaci</i> Genn. (European populations) have been observed on plants at the place of production on official inspections carried out at least once each three weeks during the nine weeks prior to marketing,</p> <p>or</p> <p>(c) in cases where <i>Bemisia tabaci</i> Genn. (European populations) has been found at the place of production, the plants, held or produced in this place of production have undergone an appropriate treatment to ensure freedom from <i>Bemisia tabaci</i> Genn. (European populations) and subsequently this place of production shall have been found free from <i>Bemisia tabaci</i> Genn. (European populations) as a consequence of the implementation of appropriate procedures aiming at eradicating <i>Bemisia tabaci</i> Genn. (European populations), in both official inspections carried out weekly during the three weeks prior to the movement from this place of production and in monitoring procedures throughout the said period. The last inspection of the above weekly inspections shall be carried out immediately prior to the above movement,</p> <p>and</p> <p>(d) evidence is available that the plants have been produced from cuttings which:</p> <p>(da) originate in an area known to be free from <i>Bemisia tabaci</i> Genn. (European populations),</p> <p>or</p> <p>(db) have been grown at a place of production where no signs of <i>Bemisia tabaci</i> Genn. (European populations) have been observed on official inspections carried out at least once each three weeks during the whole production period of these plants,</p> <p>or</p> <p>(dc) in cases where <i>Bemisia tabaci</i> Genn. (European populations) has been found at the place of production, have been grown on plants held or produced in this place</p>	<p>IRL, P (►M17 Azores, Beira Interior, Beira Litoral, Entre Douro e Minho, Madeira, Ribatejo e Oeste (communes of Alcobaça, Alenquer, Bombarral, Cadaval, Caldas da Rainha, Lourinhã, Nazaré, Obidos, Peniche and Torres Vedras) and Trás-os-Montes ◀), FI, S, UK</p>

		<p>of production having undergone an appropriate treatment to ensure freedom from <i>Bemisia tabaci</i> Genn. (European populations) and subsequently this place of production shall have been found free from <i>Bemisia tabaci</i> Genn. (European populations) as a consequence of the implementation of appropriate procedures aiming at eradicating <i>Bemisia tabaci</i> Genn. (European populations), in both official inspections carried out weekly during the three weeks prior to the movement from this place of production and in monitoring procedures throughout the said period. The last inspection of the above weekly inspections shall be carried out immediately prior to the above movement.</p>	
<p>24.3.</p>	<p>Plants of <i>Begonia</i> L., intended for planting, other than seeds, tubers and corms, and plants of <i>Ficus</i> L. and <i>Hibiscus</i> L., intended for planting, other than seeds, other than those for which there shall be evidence by their packing or their flower development or by other means that they are intended for sale to final consumers not involved in professional plant production</p>	<p>Without prejudice to the requirements applicable to the plants listed in Annex IV(A)(I)(45.1), where appropriate, official statement that:</p> <p>(a) the plants originate in an area known to be free from <i>Bemisia tabaci</i> Genn. (European populations),</p> <p>or</p> <p>(b) no signs of <i>Bemisia tabaci</i> Genn. (European populations) have been observed on plants at the place of production on official inspections carried out at least once each three weeks during the nine weeks prior to marketing,</p> <p>or</p> <p>(c) in cases where <i>Bemisia tabaci</i> Genn. (European populations) has been found at the place of production, the plants, held or produced in this place of production have undergone an appropriate treatment to ensure freedom from <i>Bemisia tabaci</i> Genn. (European populations) and subsequently this place of production shall have been found free from <i>Bemisia tabaci</i> Genn. (European populations) as a consequence of the implementation of appropriate procedures aiming at eradicating <i>Bemisia tabaci</i> Genn. (European populations), in both official inspections carried out weekly during the three weeks prior to the movement from this place of production and in monitoring procedures throughout the said period. The last inspection of the above weekly inspections shall be carried out immediately prior to the above movement.</p>	<p>IRL, P (►M17 Azores, Beira Interior, Beira Litoral, Entre Douro e Minho, Madeira, Ribatejo e Oeste (communes of Alcobaça, Alenquer, Bombarral, Cadaval, Caldas da Rainha, Lourinhã, Nazaré, Obidos, Peniche and Torres Vedras) and Trás-os-Montes ◀), FI, S, UK</p>

B. *BEMISIA TABACI*, VIRUSES AND BIOLOGICAL FEATURES

1. Host plants for *B. tabaci*

Table B.1: Lab-verified host plants (49 species and varieties — 11 families)

Family	Species
Reference: Simmons et al., (2008)	
Aizoaceae	<i>Molugo verticillata</i> L.
Aizoaceae	<i>Trianthema portulacastrum</i> L.
Asteraceae	<i>Carduus spompsissimus</i> Walker
Asteraceae	<i>Eupatorium capilifolium</i> (Lam.)
Asteraceae	<i>Gnaphalium obtusifolium</i> L.
Caryophyllaceae	<i>Arenaria serpyllifolia</i> L.
Commelinaceae	<i>Commelina communis</i> L.
Convolvulaceae	<i>Dichondra carolinensis</i> Mish.
Convolvulaceae	<i>Ipomoea alba</i> L.
Convolvulaceae	<i>Ipomoea amnicola</i> Morong
Convolvulaceae	<i>Ipomoea argillicola</i> Johnson
Convolvulaceae	<i>Ipomoea coptica</i> (L.) Roth
Convolvulaceae	<i>Ipomoea cynanchifolia</i> (Meissn.) Mart.
Convolvulaceae	<i>Ipomoea diamantinensis</i> Eardley
Convolvulaceae	<i>Ipomoea eriocarpa</i> R. Brown
Convolvulaceae	<i>Ipomoea graminea</i> R. Brown
Convolvulaceae	<i>Ipomoea hederifolia</i> L.
Convolvulaceae	<i>Ipomoea hildebrandtii</i> Vatke
Convolvulaceae	<i>Ipomoea iacunosa</i> L.
Convolvulaceae	<i>Ipomoea leptophylla</i> Torrey
Convolvulaceae	<i>Ipomoea lindheimeri</i> Gray
Convolvulaceae	<i>Ipomoea littoralis</i> (L.) Blume (= <i>I. gracilis</i> R. Brown)
Convolvulaceae	<i>Ipomoea lonchophylla</i> Black
Convolvulaceae	<i>Ipomoea muelleri</i> Benth.
Convolvulaceae	<i>Ipomoea ochracea</i> (Lindley) Don.
Convolvulaceae	<i>Ipomoea pandurata</i> (L.) Meyer
Convolvulaceae	<i>Ipomoea parasitica</i> (Kunth) Don.
Convolvulaceae	<i>Ipomoea pedicellaris</i> Bentham
Convolvulaceae	<i>Ipomoea pes-tigridis</i> L.
Convolvulaceae	<i>Ipomoea plebeia</i> R. Brown
Convolvulaceae	<i>Ipomoea quamoclit</i> L.
Convolvulaceae	<i>Ipomoea ramosissima</i> (Poiret) Choisy
Convolvulaceae	<i>Ipomoea tabascana</i> Sprague & Sandw.
Convolvulaceae	<i>Ipomoea tenuissima</i> Choisy
Convolvulaceae	<i>Ipomoea ternifolia</i> Cavanilles
Convolvulaceae	<i>Ipomoea tiliacea</i> (Willd.) Choisy
Convolvulaceae	<i>Ipomoea triloba</i> L.

Family	Species
Reference: Simmons et al., (2008)	
Convolvulaceae	<i>Ipomoea turbinata</i> Lagasca & Segura
Convolvulaceae	<i>Ipomoea umbraticola</i> House
Convolvulaceae	<i>Ipomoea wrightii</i> Gray
Fabaceae	<i>Centrosema virginianum</i> L. Benth.
Lamiaceae	<i>Glechoma hederacea</i> L.
Lamiaceae	<i>Stachys floridana</i> Shuttlew.
Poaceae	<i>Avena sativa</i> L.
Poaceae	<i>Panicum miliaceum</i> L.
Poaceae	<i>Triticum aestivum</i> L.
Rosaceae	<i>Rubus laciniatus</i> Willd
Sterculiaceae	<i>Melochia corchorifolia</i> L.
Vitaceae	<i>Parthenocissus quinquefolia</i> (L.) Planch.

Table B2: Field-verified host plants (509 species and varieties — 102 families)

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Acanthaceae	<i>Adhatoda vasica</i>	3
Acanthaceae	<i>Barleria cristata</i>	3
Acanthaceae	<i>Justicia atroata</i> L.	4
Acanthaceae	<i>Pachystachys lutea</i>	3
Acanthaceae	<i>Sunchegia nolilis</i>	3
Aceraceae	<i>Acer buergerianum</i>	3
Aceraceae	<i>Acer palmatum</i>	3
Agavaceae	<i>Agave americana</i>	3
Aizoaceae	<i>Mollugo pentaphylla</i>	3
Amaranthaceae	<i>Achyranthes aspera</i>	3
Amaranthaceae	<i>Alternanthera philoxeroides</i>	3
Amaranthaceae	<i>Amaranthus albus</i> L.	4
Amaranthaceae	<i>Amaranthus caudatus</i>	3, 5
Amaranthaceae	<i>Amaranthus graecizans</i> L.	4
Amaranthaceae	<i>Amaranthus hybridus</i> L.	4
Amaranthaceae	<i>Amaranthus mangostanus</i>	3
Amaranthaceae	<i>Amaranthus retroflexus</i>	3, 4
Amaranthaceae	<i>Amaranthus spinosus</i>	3, 4
Amaranthaceae	<i>Amaranthus tricolor</i>	3
Amaranthaceae	<i>Amaranthus viridis</i> L.	3, 4
Amaranthaceae	<i>Celosia argentea</i>	3
Amaranthaceae	<i>Celosia argentea</i> L. CV. <i>phunosa</i>	3
Amaranthaceae	<i>Celosia cristata</i>	3

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Amaranthaceae	<i>Gomphrena globosa</i>	3
Amaryllidaceae	<i>Hippeastrum vittatum</i>	3
Amaryllidaceae	<i>Lycoris radiata</i>	3
Apiaceae	<i>Daucus carota</i> L. var. <i>sativa</i> DC	4
Apocynaceae	<i>Allamanda cathartica</i>	3
Apocynaceae	<i>Catharanthus roseus</i>	3
Apocynaceae	<i>Nerium indicum</i>	3
Apocynaceae	<i>Nerium oleander</i> L.	4
Apocynaceae	<i>Plumeria rubra</i>	3
Apocynaceae	<i>Vinca major</i>	3
Apocynaceae	<i>Vinca major</i> 'Variegata'	3
Aquifoliaceae	<i>Ilex latifolia</i>	3
Araceae	<i>Alocasia macrorrhiza</i>	3
Araceae	<i>Caladium bicolor</i>	3
Araceae	<i>Colocasia esculenta</i>	3
Araceae	<i>Philodendron selloum</i>	3
Araceae	<i>Scindapsus aureus</i>	3
Araceae	<i>Spathiphyllum palls</i>	3
Araceae	<i>Syngonium barry</i>	3
Araliaceae	<i>Fatsia japonica</i>	3
Araliaceae	<i>Hedera helix</i>	3
Araliaceae	<i>Polyscias carolorum</i>	3
Arecaceae	<i>Rhapis excelsa</i> (Thunb.) A. Henry	3
Aristolochiaceae	<i>Aristolochia</i> sp.	5
Asclepiadaceae	<i>Dischidia nummularia</i>	3
Asclepiadaceae	<i>Leptadenia heterophylla</i>	5
Asclepiadaceae	<i>Telosma cordarum</i>	3
Asteraceae	<i>Ageratum conyzoides</i>	3, 5
Asteraceae	<i>Aster</i> sp.	5
Asteraceae	<i>Bellis perennis</i>	3
Asteraceae	<i>Bidena bipinnata</i>	3, 5
Asteraceae	<i>Bidens pilosa</i>	3, 5
Asteraceae	<i>Calendula officinalis</i>	3
Asteraceae	<i>Carthamus tinctorius</i>	5
Asteraceae	<i>Cerbera jamesonii</i>	3
Asteraceae	<i>Chrysanthemum cornarium</i>	3
Asteraceae	<i>Chrysanthemum morifolium</i>	3
Asteraceae	<i>Chrysanthemum nankingensis</i>	3
Asteraceae	<i>Chrysanthemum segetum</i> L.	4
Asteraceae	<i>Cichorium endivia</i>	5
Asteraceae	<i>Cichorium endivia</i> subsp. <i>pumilum</i>	5
Asteraceae	<i>Cichorium intybus</i>	3

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Asteraceae	<i>Cirsium japonicum</i>	3
Asteraceae	<i>Cirsium setosum</i>	3
Asteraceae	<i>Conyza bonariensis</i> L.	3, 4
Asteraceae	<i>Conyza canadensis</i> (L.)	4
Asteraceae	<i>Conyza dioscoridis</i>	5
Asteraceae	<i>Cosmos sulphureus</i>	3
Asteraceae	<i>Dahlia pinnate</i>	3
Asteraceae	<i>Dendranthema chanelii</i>	3
Asteraceae	<i>Dendranthema indicum</i>	3
Asteraceae	<i>Eclipta prostrata</i>	3
Asteraceae	<i>Emilia sonchifolia</i>	3
Asteraceae	<i>Erigeron breviscapus</i>	3
Asteraceae	<i>Erigeron canadensis</i>	3
Asteraceae	<i>Gerbera jamesonii</i> H. Bolus ex Hook f.	4
Asteraceae	<i>Gynura crepidioides</i>	3
Asteraceae	<i>Helianthus annuus</i> L.	3, 4, 5
Asteraceae	<i>Helianthus debilis</i>	5
Asteraceae	<i>Helianthus tuberosus</i>	3, 5
Asteraceae	<i>Lactuca brevirostris</i>	3
Asteraceae	<i>Lactuca sativa</i>	5
Asteraceae	<i>Lactuca sativa</i> var. <i>angustana</i>	3
Asteraceae	<i>Lactuca sativa</i> var. <i>asparagina</i>	3
Asteraceae	<i>Lactuca sativa</i> var. <i>capitata</i>	3
Asteraceae	<i>Lactuca sativa</i> var. <i>crispa</i>	3
Asteraceae	<i>Lactuca sativa</i> var. <i>longifolia</i>	3
Asteraceae	<i>Lactuca serriola</i> L.	4
Asteraceae	<i>Laumaea</i> sp.	5
Asteraceae	<i>Melampodium 'Lemon Delight'</i>	3
Asteraceae	<i>Osteospermum ecklonis</i>	3
Asteraceae	<i>Siegesbeckia glabrescens</i>	3
Asteraceae	<i>Siegesbeckia orientalis</i>	3
Asteraceae	<i>Sonchus arvensis</i> L.	3, 4
Asteraceae	<i>Sonchus asper</i> (L.)	4
Asteraceae	<i>Sonchus oleraceus</i> L.	3, 4, 5
Asteraceae	<i>Synedrella nodiflora</i>	3
Asteraceae	<i>Tagetes erecta</i>	3
Asteraceae	<i>Tagetes patula</i>	3
Asteraceae	<i>Taraxacum mongolicum</i>	3
Asteraceae	<i>Wedelia chinensis</i>	3
Asteraceae	<i>Xanthium sibiricum</i>	3
Asteraceae	<i>Xanthium strumarium</i> L.	4, 5
Asteraceae	<i>Youngia japonica</i>	3

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Asteraceae	<i>Zinnia elegans</i>	3, 5
Averrhoaceae	<i>Averrhoa carambola</i>	3
Balsaminaceae	<i>Impatiens balsamina</i>	3
Basellaceae	<i>Basella rubra</i>	3
Begoniaceae	<i>Begonia ravenii</i>	3
Begoniaceae	<i>Begonia simperflorens</i>	3
Berberidaceae	<i>Berberis thunbergii</i>	3
Berberidaceae	<i>Nandina domestica</i> Thunberg	3, 4
Bignoniaceae	<i>Campsis grandiflora</i>	3
Bignoniaceae	<i>Campsis radicans</i> (L.) Seem.	4
Bignoniaceae	<i>Catalpa bignonioides</i> Walt.	4
Bombacaceae	<i>Ceiba pentandra</i>	3
Bombacaceae	<i>Pachira macrocarpa</i>	3
Boraginaceae	<i>Ehretia microphylla</i>	3
Boraginaceae	<i>Heliothropium europaeum</i>	5
Brassicaceae	<i>Allaria petiolata</i> (Bieb.)	4
Brassicaceae	<i>Brassica oleracea</i> var. <i>italica</i>	4
Brassicaceae	<i>Brassica alboglabra</i>	3
Brassicaceae	<i>Brassica campestris</i>	3, 5
Brassicaceae	<i>Brassica campestris</i> ssp. <i>chinensis</i> var. <i>communis</i>	3
Brassicaceae	<i>Brassica campestris</i> ssp. <i>chinensis</i> var. <i>utilis</i>	3
Brassicaceae	<i>Brassica campestris</i> ssp. var. <i>pekinensis</i>	3
Brassicaceae	<i>Brassica chinensis</i>	3
Brassicaceae	<i>Brassica juncea</i> var. <i>capitata</i>	3
Brassicaceae	<i>Brassica juncea</i> var. <i>foliosa</i>	3
Brassicaceae	<i>Brassica juncea</i> var. <i>megarrhiza</i>	3
Brassicaceae	<i>Brassica juncea</i> var. <i>multiceps</i>	3
Brassicaceae	<i>Brassica juncea</i> var. <i>tumida</i>	3
Brassicaceae	<i>Brassica oleracea</i> <i>botrytis</i>	3, 4, 5
Brassicaceae	<i>Brassica oleracea</i> <i>capitata</i>	3, 5
Brassicaceae	<i>Brassica oleracea</i> var. <i>acephala</i>	3
Brassicaceae	<i>Brassica oleracea</i> var. <i>capitata</i> subvar. <i>alba</i>	4
Brassicaceae	<i>Brassica oleracea</i> var. <i>caulorapa</i>	3
Brassicaceae	<i>Brassica oleracea</i> var. <i>italica</i>	3
Brassicaceae	<i>Brassica rapa</i>	5
Brassicaceae	<i>Capsella bursa-pastoris</i> L.	3, 4
Brassicaceae	<i>Daucus carota</i>	3
Brassicaceae	<i>Nasturtium officinale</i>	3
Brassicaceae	<i>Raphanus raphanistrum</i> L.	4
Brassicaceae	<i>Raphanus sativus</i> var. <i>longipinnatus</i>	3
Brassicaceae	<i>Rorippa dubia</i>	3
Brassicaceae	<i>Rorippa indica</i>	3

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Brassicaceae	<i>Sinapis arvensis</i>	5
Brassicaceae	<i>Zylla myagroides</i>	5
Buxaceae	<i>Buxus harlandii</i>	3
Buxaceae	<i>Buxus megistophylla</i>	3
Buxaceae	<i>Buxus sinica</i>	3
Caesalpiniaceae	<i>Cassia suffruticosa</i>	3
Caesalpiniaceae	<i>Cassia surattensis</i>	3
Calycanthaceae	<i>Calycanthus xoridus</i> L.	4
Campanulaceae	<i>Campanula rapunculus</i>	3
Cannabinaceae	<i>Humulus scandens</i>	3
Capparidaceae	<i>Capparis ovata</i> Desf.	4
Capparidaceae	<i>Capparis spinosa</i> L.	4
Capparidaceae	<i>Cleome gynandra</i>	5
Capparidaceae	<i>Cleome spinosa</i>	3
Caprifoliaceae	<i>Lonicera japonica</i> Thunb.	3, 4
Caprifoliaceae	<i>Lonicera sempervirens</i>	3
Caprifoliaceae	<i>Viburnum opulus</i> L.	4
Caprifoliaceae	<i>Viburnum tinus</i> L.	4
Caprifoliaceae	<i>Weigela xorida</i> (Bunge)	4
Caricaceae	<i>Carica papaya</i>	3
Celastraceae	<i>Euonymus bungeanus</i>	3
Chenopodiaceae	<i>Beta vulgaris</i> L.	4
Chenopodiaceae	<i>Beta vulgaris</i> var. <i>rapa</i>	5
Chenopodiaceae	<i>Chenopodium album</i> L.	3, 4, 5
Chenopodiaceae	<i>Chenopodium ambrosioides</i>	3, 5
Chenopodiaceae	<i>Chenopodium murale</i>	5
Chenopodiaceae	<i>Spinacia oleracea</i>	3
Cistaceae	<i>Cistus creticus</i> L.	4
Cistaceae	<i>Cistus salviaefolius</i> L.	4
Cistaceae	<i>Cistus villosus</i> L.	4
Combretaceae	<i>Quisqualis indica</i>	3
Commelinaceae	<i>Setcreasea purpurea</i>	3
Commelinaceae	<i>Zebrina pendula</i>	3
Convolvulaceae	<i>Calystegia hederacwa</i>	3
Convolvulaceae	<i>Convolvulus arvensis</i> L.	4
Convolvulaceae	<i>Dichondra repens</i>	3
Convolvulaceae	<i>Ipomoea aquatica</i>	3
Convolvulaceae	<i>Ipomoea batatas</i>	3
Convolvulaceae	<i>Ipomoea hederacea</i> (L.) Jacq.	4
Convolvulaceae	<i>Ipomoea purpurea</i> Roth.	4
Convolvulaceae	<i>Ipomoea sagittata</i> Poir.	4
Convolvulaceae	<i>Ipomoea stolonifera</i> (Cyr.)	4

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Convolvulaceae	<i>Pentas lanceolata</i>	3
Convolvulaceae	<i>Pharbitis nil</i>	3
Convolvulaceae	<i>Quamolit coccinea</i>	3
Convolvulaceae	<i>Quamolit pennata</i>	3
Cornaceae	<i>Aucuba japonica</i>	3
Crassulaceae	<i>Crassula arborescens</i>	3
Crassulaceae	<i>Hylotelephium erythrostictum</i>	3
Crassulaceae	<i>Kalanchoe blossfeldiana</i>	3
Crassulaceae	<i>Sedum adolphii</i>	3
Cucurbitaceae	<i>Benincasa hispida</i>	3
Cucurbitaceae	<i>Benincasa hispida</i> var. <i>chiehqua</i>	3
Cucurbitaceae	<i>Citrullus colocynthis</i>	5
Cucurbitaceae	<i>Citrullus lanatus</i> (Thunb.)	3, 4, 5
Cucurbitaceae	<i>Cucumis melo</i> L.	3, 4
Cucurbitaceae	<i>Cucumis melo</i> var. <i>conomon</i>	3
Cucurbitaceae	<i>Cucumis melo</i> var. <i>flexuosus</i>	3
Cucurbitaceae	<i>Cucumis sativus</i> L.	3, 4, 5
Cucurbitaceae	<i>Cucurbita maxima</i>	5
Cucurbitaceae	<i>Cucurbita moschata</i>	3
Cucurbitaceae	<i>Cucurbita moschata</i> var. <i>meloformis</i>	3
Cucurbitaceae	<i>Cucurbita moschata</i> var. <i>toonaa</i>	3
Cucurbitaceae	<i>Cucurbita pepo</i> L.	3, 4
Cucurbitaceae	<i>Cucurbita pepo ovifera</i>	5
Cucurbitaceae	<i>Lagenaria cylindrica</i>	3
Cucurbitaceae	<i>Lagenaria siceraria</i>	3
Cucurbitaceae	<i>Lagenaria siceraria</i> var. <i>hispida</i>	3
Cucurbitaceae	<i>Luffa acutangula</i>	3
Cucurbitaceae	<i>Luffa cylindrica</i>	3
Cucurbitaceae	<i>Momordica balsamina</i> L.	4
Cucurbitaceae	<i>Momordica charantia</i>	3
Cucurbitaceae	<i>Sechium edule</i>	3
Cucurbitaceae	<i>Trichosanthes anguina</i>	3
Cuscutaceae	<i>Cuscuta chinensis</i>	3
Dioscoreaceae	<i>Dioscorea opposita</i>	3
Ebenaceae	<i>Diospyros discdot</i>	3
Ebenaceae	<i>Diospyros kaki</i> L.	3, 4
Ericaceae	<i>Rhododendron simsii</i>	3
Euphorbiaceae	<i>Acalypha australis</i>	3
Euphorbiaceae	<i>Acalypha wilkesiana</i>	3
Euphorbiaceae	<i>Alchornea trewioides</i>	3
Euphorbiaceae	<i>Codiaeum variegatum</i>	3
Euphorbiaceae	<i>Euphorbia cuneata</i>	5

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Euphorbiaceae	<i>Euphorbia geniculata</i>	5
Euphorbiaceae	<i>Euphorbia helioscopia</i> L.	4, 5
Euphorbiaceae	<i>Euphorbia heterophylla</i>	3
Euphorbiaceae	<i>Euphorbia hirta</i>	3
Euphorbiaceae	<i>Euphorbia humifusa</i>	3
Euphorbiaceae	<i>Euphorbia hypericifolia</i>	5
Euphorbiaceae	<i>Euphorbia milii</i>	3
Euphorbiaceae	<i>Euphorbia milii</i> var. <i>splendes</i> Boj. ex Hook.	4
Euphorbiaceae	<i>Euphorbia neriiifolia</i> L.	4
Euphorbiaceae	<i>Euphorbia nutans</i> L.	4
Euphorbiaceae	<i>Euphorbia peplus</i> L.	4, 5
Euphorbiaceae	<i>Euphorbia pulcherrima</i> Willdenow ex Klotzsch (poinsettia)	3, 4, 5
Euphorbiaceae	<i>Euphorbia supina</i> Raf	4
Euphorbiaceae	<i>Jatropha podagrica</i>	3
Euphorbiaceae	<i>Manihot esculenta</i>	3
Euphorbiaceae	<i>Mercurialis annua</i> L.	4
Euphorbiaceae	<i>Ricinus communis</i> L.	3, 4, 5
Euphorbiaceae	<i>Sauropus macranthus</i>	3
Fabaceae	<i>Acacia dealbata</i> Link.	4
Fabaceae	<i>Acacia tortilis</i>	5
Fabaceae	<i>Albizia julibrissin</i>	3
Fabaceae	<i>Alhagi maurorum</i>	5
Fabaceae	<i>Arachis hypogaea</i> L.	3, 4
Fabaceae	<i>Astragalus sinicus</i>	3
Fabaceae	<i>Bauhinia kruzii</i>	5
Fabaceae	<i>Bauhinia variegata</i> L.	4
Fabaceae	<i>Caesalpinia pulcherrima</i>	5
Fabaceae	<i>Cassia tora</i>	3
Fabaceae	<i>Cercis chinensis</i>	3
Fabaceae	<i>Cercis siliquastrum</i> L.	4
Fabaceae	<i>Dalbergia sissoo</i> Roxb.	4
Fabaceae	<i>Erythrina crista-galli</i> L.	4
Fabaceae	<i>Glycine max</i> (L.) Merrill	3, 4, 5
Fabaceae	<i>Glycine soja</i>	3
Fabaceae	<i>Ismailia</i>	5
Fabaceae	<i>Lablab purpureus</i>	3, 5
Fabaceae	<i>Lathyrus angulatus</i>	5
Fabaceae	<i>Lotus arabicus</i>	5
Fabaceae	<i>Medicago sativa</i> L.	3, 4
Fabaceae	<i>Millettia reticulata</i>	3
Fabaceae	<i>Mimosa pudica</i>	3
Fabaceae	<i>Pachyrrhizus erosus</i>	3

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Fabaceae	<i>Parkinsonia aculeata</i>	5
Fabaceae	<i>Phaseolus angularis</i>	3
Fabaceae	<i>Phaseolus aureus</i>	3
Fabaceae	<i>Phaseolus vulgaris</i> L.	3, 4, 5
Fabaceae	<i>Physalis alkekengi</i> L.	4
Fabaceae	<i>Physalis angulata</i> L.	3, 4
Fabaceae	<i>Pisum sativum</i>	3
Fabaceae	<i>Poinciana elata</i>	5
Fabaceae	<i>Psophocarpus tetragonolobus</i>	3
Fabaceae	<i>Pueraria lobata</i>	3
Fabaceae	<i>Pueraria thomsonii</i>	3
Fabaceae	<i>Robinia pseudoacacia</i>	3
Fabaceae	<i>Senna alata</i>	5
Fabaceae	<i>Sophora japonica</i> f. <i>pendula</i>	3
Fabaceae	<i>Sophora japonica</i>	3
Fabaceae	<i>Trifolium repens</i> L.	3, 4
Fabaceae	<i>Vicia faba</i>	5
Fabaceae	<i>Vicia sativa</i>	5
Fabaceae	<i>Vigna radiata</i>	3
Fabaceae	<i>Vigna unguiculata</i> L.	3, 4, 5
Fagaceae	<i>Quercus coccifera</i> L.	4
Geraniaceae	<i>Geranium wilfordii</i>	3
Geraniaceae	<i>Pelargonium hortorum</i>	3
Geraniaceae	<i>Pelargonium odoratissimum</i>	3
Gesneriaceae	<i>Columnnea gloriosa</i>	3
Hamamelidaceae	<i>Lorpetalum chinense</i> var. <i>rubrum</i>	3
Hydrangeaceae	<i>Hydrangea macrophylla</i> (Thunberg) Seringe	3, 4
Iridaceae	<i>Iris tectorum</i>	3
Juglandaceae	<i>Caria illinoensis</i> (Wangenh) Koch.	4
Juglandaceae	<i>Juglans nigra</i> L.	4
Lamiaceae	<i>Coleus blumei</i>	3
Lamiaceae	<i>Lamium amplexicaule</i> L.	4
Lamiaceae	<i>Leonurus artemisia</i>	3
Lamiaceae	<i>Mentha arvensis</i> L.	4
Lamiaceae	<i>Mentha haplocalyx</i>	3
Lamiaceae	<i>Mentha piperita</i> L.	4
Lamiaceae	<i>Mentha sativa</i> L.	4, 5
Lamiaceae	<i>Ocimum basilicum</i>	5
Lamiaceae	<i>Perilla frutescens</i>	3
Lamiaceae	<i>Salvia aucheri</i>	4
Lamiaceae	<i>Salvia pratensis</i> L.	4
Lamiaceae	<i>Salvia sclarea</i> L.	4

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Lamiaceae	<i>Salvia splendens</i>	3
Lamiaceae	<i>Salvia triloba</i> L.	4
Lamiaceae	<i>Scutellaria baicalensis</i>	3
Lamiaceae	<i>Scutellaria barbata</i>	3
Lamiaceae	<i>Stachys arvensis</i> (L.)	4
Lardizabalaceae	<i>Sargentodoxa cuneata</i>	3
Lauraceae	<i>Laurus nobilis</i> L.	4
Lauraceae	<i>Persea americana</i> Miller	4
Liliaceae	<i>Asparagus officinalis</i>	3
Liliaceae	<i>Asparagus setaceus</i>	3
Liliaceae	<i>Dracaena fragrans</i> var. <i>victoria</i>	3
Liliaceae	<i>Liriope palatyphylla</i>	3
Liliaceae	<i>Ophiopogon japonicus</i>	3
Lythraceae	<i>Cuphea lanceolata</i>	3
Lythraceae	<i>Lagerstroemia indica</i> L.	3, 4
Lythraceae	<i>Lawsonia inermis</i>	5
Lythraceae	<i>Woodfordia fruticosa</i>	3
Magnoliaceae	<i>Chlorophytum comosum</i>	3
Magnoliaceae	<i>Hosta plantaginea</i>	3
Magnoliaceae	<i>Hosta ventricosa</i>	3
Magnoliaceae	<i>Liriodendron chinense</i>	3
Magnoliaceae	<i>Magnolia denudate</i>	3
Magnoliaceae	<i>Magnolia grandiflora</i>	3
Magnoliaceae	<i>Michelia maudiae</i>	3
Malvaceae	<i>Abelmoschus moschatus</i>	3
Malvaceae	<i>Abutilon hybriden</i>	4
Malvaceae	<i>Abutilon striatum</i> Dicks. ex Lind.	4
Malvaceae	<i>Abutilon theophrasti</i> Medicus	3,4
Malvaceae	<i>Alcea pallida</i> Waldst and Kit.	4
Malvaceae	<i>Alcea striata</i> Alef.	4
Malvaceae	<i>Althaea cannabina</i>	5
Malvaceae	<i>Althaea rosea</i>	5
Malvaceae	<i>Gossypium barbadence</i>	5
Malvaceae	<i>Gossypium hirsutum</i>	3
Malvaceae	<i>Hibiscus esculentus</i>	3, 5
Malvaceae	<i>Hibiscus mutabilis</i>	3
Malvaceae	<i>Hibiscus rosa-sinensis</i> L.	3, 4
Malvaceae	<i>Hibiscus rosa-sinensis</i> var. <i>cooperi</i>	3
Malvaceae	<i>Hibiscus sabdariff</i>	5
Malvaceae	<i>Hibiscus syriacus</i> L.	3, 4
Malvaceae	<i>Hibiscus trionum</i> L.	4
Malvaceae	<i>Malva neglecta</i> Wallr.	4

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Malvaceae	<i>Malva crispa</i>	3
Malvaceae	<i>Malva rotundifolia</i>	5
Malvaceae	<i>Malva sylvestris</i> L.	4, 5
Malvaceae	<i>Sida rhombifolia</i>	3
Malvaceae	<i>Urena lobata</i>	3
Meliaceae	<i>Melia azedarach</i>	3
Meliaceae	<i>Toona sinensis</i>	3
Moraceae	<i>Broussonetia papyrifera</i>	3
Moraceae	<i>Ficus carica</i>	3, 5
Moraceae	<i>Ficus hispida</i>	3
Moraceae	<i>Ficus religiosa</i>	3
Moraceae	<i>Morus alba</i> L.	3, 4
Moraceae	<i>Morus nigra</i> L.	4
Musaceae	<i>Musa acuminata</i>	3
Myrtaceae	<i>Eucalyptus urophylla</i>	3
Myrtaceae	<i>Psidium guajava</i>	3, 5
Nepenthaceae	<i>Nepenthes mirabilis</i>	3
Nyctaginaceae	<i>Bougainvillea</i> sp.	4
Nyctaginaceae	<i>Forsythia intermedia</i> Zabel	4
Nyctaginaceae	<i>Jasminum fruticans</i> L.	4
Nyctaginaceae	<i>Jasminum officinale</i> L.	4
Nyctaginaceae	<i>Jasminum sambac</i> L.	3, 4
Nyctaginaceae	<i>Ligustrum ovalifolium</i> L.	4
Oleaceae	<i>Fraxinus szaboana</i>	3
Oleaceae	<i>Jasminum mesnyi</i>	3
Oleaceae	<i>Jasminum nudiflorum</i>	3
Oleaceae	<i>Ligustrum lucidum</i>	3
Oleaceae	<i>Ligustrum quihoui</i>	3
Oleaceae	<i>Ligustrum vicaryi</i>	3
Oleaceae	<i>Osmanthus fragrans</i>	3
Onagraceae	<i>Jussiaea linifolia</i>	3
Onagraceae	<i>Ludwigia prostrate</i>	3
Oxalidaceae	<i>Oxalis corniculata</i>	3
Paeoniaceae	<i>Paeonia lactiflora</i>	3
Passifloraceae	<i>Passiflora edulis</i>	3
Pedaliaceae	<i>Sesamum indicum</i>	3
Phytolaccaceae	<i>Phytolacca americana</i>	3
Piperaceae	<i>Piper cubeba</i>	5
Plantaginaceae	<i>Plantago major</i>	5
Platanaceae	<i>Platanus acerifolia</i>	3
Poaceae	<i>Cynodon dactylon</i>	5
Polygalaceae	<i>Polygala chinensis</i>	3

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Polygonaceae	<i>Polygonum amphibium</i> L.	4
Polygonaceae	<i>Polygonum aviculare</i> L.	4
Polygonaceae	<i>Polygonum chinensis</i>	3
Polygonaceae	<i>Polygonum convolvulus</i> L.	4
Polygonaceae	<i>Polygonum hydropiper</i> L.	4
Polygonaceae	<i>Polygonum orientale</i>	3
Polygonaceae	<i>Polygonum perfoliatum</i>	3
Polygonaceae	<i>Polygonum persicaria</i> L.	4
Polygonaceae	<i>Rheum palmatum</i>	3
Polygonaceae	<i>Rumex acetosella</i> L.	4
Portulacaceae	<i>Portulaca grandiflora</i>	3, 5
Portulacaceae	<i>Portulaca oleracea</i> L.	3, 4
Punicaceae	<i>Punica granatum nana</i> L.	4
Punicaceae	<i>Punica granatum</i> L.	3, 4
Ranunculaceae	<i>Ranunculus asiaticus</i>	3
Rhamnaceae	<i>Sageretia theezans</i>	3
Rhamnaceae	<i>Ziziphus spina-christi</i>	5
Rhamnaceae	<i>Ziziphus zizyphus</i>	3
Rosaceae	<i>Amygdalus persica</i>	3
Rosaceae	<i>Amygdalus triloba</i>	3
Rosaceae	<i>Cerasus pseudocerasus</i>	3
Rosaceae	<i>Eriobotrya japonica</i>	3
Rosaceae	<i>Fragaria grandiflora</i>	3
Rosaceae	<i>Fragaria vesca</i>	5
Rosaceae	<i>Kerria japonica</i>	3
Rosaceae	<i>Malus halliana</i>	3
Rosaceae	<i>Malus pumila</i>	3
Rosaceae	<i>Prunus cerasifera</i> Ehrh.	4
Rosaceae	<i>Prunus persica</i> (L.)	4
Rosaceae	<i>Prunus persica</i> var. <i>nectarina</i> L.	4
Rosaceae	<i>Pyracantha fortuneana</i>	3
Rosaceae	<i>Pyrus bretschneideri</i>	3
Rosaceae	<i>Rosa chinensis</i>	3
Rosaceae	<i>Rosa multiflora</i>	3
Rosaceae	<i>Rosa rugosa</i>	3
Rosaceae	<i>Rubus fruticosus</i> L.	4
Rosaceae	<i>Spiraea vanhouetti</i> ZbL.	4
Rosaceae	<i>Spiraea japonica</i>	3
Rubiaceae	<i>Coffea arabica</i>	5
Rubiaceae	<i>Gardenia jasminoides</i>	3
Rubiaceae	<i>Gardenia jasminoides</i> var. <i>dortu</i>	3
Rubiaceae	<i>Hamelia patens</i>	3

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Rubiaceae	<i>Hedyotis auricularia</i>	3
Rutaceae	<i>Citrus limon</i>	4, 5
Rutaceae	<i>Citrus madurensis</i>	3
Rutaceae	<i>Citrus paradisi</i> Macfad.	4
Rutaceae	<i>Citrus sinensis</i> (L.)	4, 5
Rutaceae	<i>Clausena lansium</i>	3
Rutaceae	<i>Forunella margarita</i>	3
Rutaceae	<i>Murraya paniculata</i>	3
Rutaceae	<i>Zanthoxylum bungeanum</i>	3
Salicaceae	<i>Salix matsudana</i> G. Koidzumi	4
Sapindaceae	<i>Koelreuteria paniculata</i> Laxmann	3, 4
Sapotaceae	<i>Manilkura zapota</i>	3
Scrophulariaceae	<i>Lindernia crustacean</i>	3
Scrophulariaceae	<i>Rehmarnia glufinosa</i>	3
Simaroubaceae	<i>Picrasma quassioides</i>	3
Solanaceae	<i>Brunfelsia latibolia</i>	3
Solanaceae	<i>Capsicum annuum</i> L.	3, 4, 5
Solanaceae	<i>Capsicum annuum</i> var. <i>cerasiforme</i>	3
Solanaceae	<i>Capsicum annuum</i> var. <i>grossum</i>	3
Solanaceae	<i>Capsicum frutescens</i>	3
Solanaceae	<i>Capsicum frutescens</i> var. <i>conoides</i>	3
Solanaceae	<i>Capsicum frutescens</i> var. <i>longum</i>	3
Solanaceae	<i>Cestrum fasciculatum</i> (SchltdL.) Miers	4
Solanaceae	<i>Cestrum nocturnum</i>	3
Solanaceae	<i>Datura metel</i> L.	4
Solanaceae	<i>Datura stramonium</i> L.	3, 4
Solanaceae	<i>Datura candida plena</i>	3
Solanaceae	<i>Datura gardeneri</i>	5
Solanaceae	<i>Datura innoxia</i> Miller	4
Solanaceae	<i>Lycium chinense</i>	3
Solanaceae	<i>Lycopersicum esculentum</i> Mil.	3, 4, 5
Solanaceae	<i>Lycopersicum esculentum</i> var. <i>cerasiforme</i>	3
Solanaceae	<i>Lycopersicum esculentum</i> var. <i>pyriforme</i>	3
Solanaceae	<i>Nicotiana tabacum</i> L.	3, 4
Solanaceae	<i>Petunia hybrida</i> Vilm.	3, 4
Solanaceae	<i>Solanum lacinatedum</i>	5
Solanaceae	<i>Solanum luteum</i> Miller	4
Solanaceae	<i>Solanum melongena</i> L.	3, 4, 5
Solanaceae	<i>Solanum muricatum</i>	3
Solanaceae	<i>Solanum nigrum</i>	3, 4, 5
Solanaceae	<i>Solanum pseudocapsicum</i>	3
Solanaceae	<i>Solanum tuberosum</i> L.	3, 4, 5

Family	Species	Ref.
References - 3: Li et al., (2011a); 4: Bayhan et al. (2006b); 5: Abd-Rabou and Simmons (2010)		
Solanaceae	<i>Withania somnifera</i>	5
Sterculiaceae	<i>Brachychiton populneum</i> (Schott and Endlicher) R. Brown	4
Sterculiaceae	<i>Firmiana platanifolia</i>	3
Sterculiaceae	<i>Glassostemon bruguieri</i>	5
Theaceae	<i>Camellia japonica</i>	3
Thymelaeaceae	<i>Daphne odora</i>	3
Tiliaceae	<i>Corchorus olitorius</i> L.	4
Umbelliferae	<i>Apium graveolens</i> var. <i>dulce</i>	3
Umbelliferae	<i>Coriandrum sativum</i>	3
Urticaceae	<i>Boehmeria nivea</i>	3
Urticaceae	<i>Pilea mollis</i>	3
Urticaceae	<i>Urtica urens</i> L.	4
Verbenaceae	<i>Clerodendrum fragrans</i>	3
Verbenaceae	<i>Clerodendrum japonicum</i>	3
Verbenaceae	<i>Clerodendrum kaempferi</i>	3
Verbenaceae	<i>Duranta repens</i> L.	3, 4, 5
Verbenaceae	<i>Lantana camara</i> L.	3, 4, 5
Vitaceae	<i>Cayratia japonica</i>	3
Vitaceae	<i>Parthenocissus heterophylla</i>	3
Vitaceae	<i>Parthenocissus tricuspidata</i>	3
Vitaceae	<i>Tecoma capensis</i>	5
Vitaceae	<i>Vitis vinifera</i> L.	3, 4, 5
Zygophyllaceae	<i>Tribulus terrestris</i> L.	4

Table B.3: Unconfirmed host plants (610 species and varieties — 105 families)

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Acanthaceae	<i>Aphelandra squarrosa</i> Nees	1, 2
Acanthaceae	<i>Asystasia gangetica</i>	2
Acanthaceae	<i>Crossandra infundibuliformis</i> (L.) Nees	1, 2
Acanthaceae	<i>Fittonia verschaffeltii</i>	1, 2
Acanthaceae	<i>Hemigraphis alternata</i> (Burm. f.) T. Anders.	1, 2
Acanthaceae	<i>Hemigraphis colorata</i>	1
Acanthaceae	<i>Hemigraphis exotica</i>	2
Acanthaceae	<i>Hygrophila angustifolia</i>	2
Acanthaceae	<i>Hygrophila corymbosa</i>	2
Acanthaceae	<i>Hygrophila costata</i>	2
Acanthaceae	<i>Hygrophila polysperma</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Acanthaceae	<i>Hygrophila siamensis</i>	2
Acanthaceae	<i>Hygrophila stricta</i>	2
Acanthaceae	<i>Justicia adhatoda</i>	2
Acanthaceae	<i>Nomaphila</i> sp.	1
Acanthaceae	<i>Pseuderanthemum atropurpureum</i>	1, 2
Acanthaceae	<i>Ruellia patula</i>	2
Acanthaceae	<i>Ruellia prostrata</i>	2
Acanthaceae	<i>Ruellia tweediana</i>	2
Acanthaceae	<i>Thunbergia alata</i>	2
Acanthaceae	<i>Thunbergia grandiflora</i> Roxb.	1, 2
Aceraceae	<i>Acer macrophyllum</i>	2
Aizoaceae	<i>Tetragonia tetragonoides</i>	2
Alismataceae	<i>Echinodorus arentinensis</i>	1
Alismataceae	<i>Echinodorus berteroi</i>	2
Alismataceae	<i>Echinodorus gabrielii</i>	2
Alismataceae	<i>Echinodorus grandiflorus</i>	2
Alismataceae	<i>Echinodorus grisebachii</i>	2
Alismataceae	<i>Echinodorus subulatus</i>	2
Alismataceae	<i>Echinodorus uruguayensis</i>	2
Amaranthaceae	<i>Alternanthera cardinalis</i>	2
Amaranthaceae	<i>Alternanthera ficoidea</i> R. Br. ex Roum. and Schult.	1, 2
Amaranthaceae	<i>Alternanthera reineckii</i>	2
Amaranthaceae	<i>Alternanthera sessilis</i>	2
Amaranthaceae	<i>Amaranthus blitum</i>	2
Amaranthaceae	<i>Amaranthus cruentus</i>	2
Amaranthaceae	<i>Digera arvensis</i>	2
Amaryllidaceae	<i>Erigone</i> sp.	2
Anacardiaceae	<i>Lansea aspleniifolia</i>	2
Anacardiaceae	<i>Odina aspleniifolia</i>	2
Anacardiaceae	<i>Schinus terebinthifolius</i> Raddi	1, 2
Annonaceae	<i>Annona muricata</i>	2
Annonaceae	<i>Annona reticulata</i>	2
Annonaceae	<i>Annona squamosa</i>	2
Annonaceae	<i>Fissistigma oldhamii</i>	2
Apiaceae	<i>Anethum graveolens</i>	2
Apiaceae	<i>Eryngium foetidum</i>	2
Apiaceae	<i>Petroselinum crispum</i>	2
Apiaceae	<i>Turgenia latifolia</i>	2
Apocynaceae	<i>Allamanda neriifolia</i>	1
Apocynaceae	<i>Allamanda schottii</i>	2
Apocynaceae	<i>Beaumontia grandiflora</i>	2
Apocynaceae	<i>Dipladenia sanderi</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Apocynaceae	<i>Mandevilla amabilis</i> (Hort. Backh.) Dress	1, 2
Apocynaceae	<i>Pachypodium bicolor</i>	1
Araceae	<i>Aglaonema</i> sp.	1
Araceae	<i>Alocasia amazonica</i>	2
Araceae	<i>Amorphophallus</i> sp.	2
Araceae	<i>Anthurium andraeanum</i>	2
Araceae	<i>Anthurium hortulanum</i>	2
Araceae	<i>Anubias barteri</i>	2
Araceae	<i>Anubias congensis</i>	2
Araceae	<i>Anubias nana</i>	1
Araceae	<i>Cryptocoryne crispatula</i>	2
Araceae	<i>Cryptocoryne spiralis</i>	2
Araceae	<i>Cryptocoryne wendtii</i>	2
Araceae	<i>Syngonium podophyllum</i> Schott	1, 2
Araceae	<i>Typhonium trilobatum</i>	2
Arecaceae	<i>Cocos nucifera</i> L.	1, 2
Aristolochiaceae	<i>Aristolochia bracteolata</i>	2
Aristolochiaceae	<i>Aristolochia cymbifera</i>	2
Aristolochiaceae	<i>Aristolochia punjabensis</i>	2
Aristolochiaceae	<i>Asarum splendens</i>	2
Asclepiadaceae	<i>Asclepias</i> sp.	2
Asclepiadaceae	<i>Cynanchum acutum</i>	2
Asclepiadaceae	<i>Morrenia odorata</i> (Hook. & Arn.) Lindl.	1, 2
Asclepiadaceae	<i>Pergularia daemia</i>	2
Asclepiadaceae	<i>Periploca graeca</i>	2
Asteraceae	<i>Acanthospermum hispidum</i>	2
Asteraceae	<i>Arctium</i> sp.	1
Asteraceae	<i>Argyranthemum</i> sp.	2
Asteraceae	<i>Artemisia dracunculus</i>	1, 2
Asteraceae	<i>Artemisia vulgaris</i>	2
Asteraceae	<i>Aspilia africana</i>	2
Asteraceae	<i>Aster tataricus</i>	2
Asteraceae	<i>Baccharis sativas</i>	1
Asteraceae	<i>Blainvillea dichotoma</i>	2
Asteraceae	<i>Blumea lacera</i>	2
Asteraceae	<i>Blumea neilgherrensis</i>	2
Asteraceae	<i>Callistephus chinensis</i>	2
Asteraceae	<i>Carthamus oxyacantha</i>	2
Asteraceae	<i>Centaurea africana</i>	2
Asteraceae	<i>Chromolaena odorata</i>	2
Asteraceae	<i>Chrysanthemum argenteum</i>	2
Asteraceae	<i>Chrysanthemum indicum</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Asteraceae	<i>Chrysanthemum morifolium</i> Ramat.	1, 2
Asteraceae	<i>Cirsium arvense</i>	2
Asteraceae	<i>Conyza aegyptiaca</i>	2
Asteraceae	<i>Conyza arvensis</i>	2
Asteraceae	<i>Coreopsis tinctoria</i>	2
Asteraceae	<i>Cosmos bipinnatus</i>	2
Asteraceae	<i>Dittrichia viscosa</i>	2
Asteraceae	<i>Echinacea pallida</i>	2
Asteraceae	<i>Echinacea purpurea</i>	2
Asteraceae	<i>Echinacea sonchifolia</i>	2
Asteraceae	<i>Emilia coccinea</i>	2
Asteraceae	<i>Emilia fosbergii</i> D. H. Nicols.	1, 2
Asteraceae	<i>Emilia javanica</i> (Burm. f.)	1, 2
Asteraceae	<i>Erigeron linifolius</i>	2
Asteraceae	<i>Eupatorium album</i>	2
Asteraceae	<i>Eupatorium cannabinum</i>	2
Asteraceae	<i>Eupatorium chinense</i>	2
Asteraceae	<i>Eupatorium hirsutum</i>	1, 2
Asteraceae	<i>Eupatorium odoratum</i> L.	1
Asteraceae	<i>Galinsoga parviflora</i>	2
Asteraceae	<i>Glebionis coronarium</i>	2
Asteraceae	<i>Helichrysum</i> sp.	2
Asteraceae	<i>Heterotheca grandiflora</i>	2
Asteraceae	<i>Heterotheca subaxillaris</i> Britt. and Rusby	1, 2
Asteraceae	<i>Inula vestita</i>	2
Asteraceae	<i>Lactuca canadensis</i>	2
Asteraceae	<i>Lactuca scariola</i>	2
Asteraceae	<i>Launaea asplenifolia</i>	2
Asteraceae	<i>Liatris pilosa</i>	2
Asteraceae	<i>Liatris spicata</i>	2
Asteraceae	<i>Mikania cordata</i>	2
Asteraceae	<i>Parthenium argentatum</i>	2
Asteraceae	<i>Parthenium hysterophorus</i> L.	1, 2
Asteraceae	<i>Pluchea foetida</i> (L.) DC. var. <i>foetida</i>	1, 2
Asteraceae	<i>Pseudelephantopus spiralis</i>	2
Asteraceae	<i>Serratula quinquefolia</i>	2
Asteraceae	<i>Shinnersia rivularis</i>	2
Asteraceae	<i>Solidago caesia</i>	2
Asteraceae	<i>Solidago canadensis</i>	2
Asteraceae	<i>Solidaster</i> sp.	1
Asteraceae	<i>Sonchus cornutus</i>	2
Asteraceae	<i>Tanacetum parthenium</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Asteraceae	<i>Taraxacum officinale</i>	2
Asteraceae	<i>Tithonia diversifolia</i> (Hemsl.) A GrayL.	1, 2
Asteraceae	<i>Trichocoronis rivularis</i>	2
Asteraceae	<i>Venidium</i> sp.	1
Asteraceae	<i>Vernonia amygdalina</i>	2
Asteraceae	<i>Vernonia anthelmintica</i>	2
Asteraceae	<i>Vernonia cinerea</i>	2
Asteraceae	<i>Vicoa vestita</i>	2
Asteraceae	<i>Zinnia angustifolia</i>	2
Asteraceae	<i>Zinnia violacea</i>	2
Balsaminaceae	<i>Impatiens hawkeri</i>	2
Bignoniaceae	<i>Radermachera sinica</i>	2
Bignoniaceae	<i>Spathodea campanulata</i>	2
Bixaceae	<i>Cochlospermum planchonii</i>	2
Bombacaceae	<i>Bombacopsis glabra</i>	2
Boraginaceae	<i>Heliotropium ovalifolium</i>	2
Boraginaceae	<i>Heliotropium sudanicum</i>	2
Boraginaceae	<i>Lithospermum</i> sp.	2
Brassicaceae	<i>Armoracia</i> sp.	2
Brassicaceae	<i>Aubrieta</i> sp.	2
Brassicaceae	<i>Brassica napus</i>	2
Brassicaceae	<i>Eruca sativa</i>	2
Brassicaceae	<i>Lepidium virginicum</i> L.	1
Brassicaceae	<i>Raphanus sativus</i>	2
Brassicaceae	<i>Sisymbrium irio</i>	2
Brassicaceae	<i>Zilla myagroides</i>	2
Campanulaceae	<i>Lobelia cardinalis</i>	2
Campanulaceae	<i>Platycodon grandiflorum</i> (Jacq.) A. DC.	1, 2
Campanulaceae	<i>Trachelium caeruleum</i>	2
Cannabinaceae	<i>Cannabis sativa</i>	2
Cannaceae	<i>Canna</i> sp.	2
Capparidaceae	<i>Boscia senegalensis</i>	2
Capparidaceae	<i>Cadaba rotundifolia</i>	2
Capparidaceae	<i>Cleome chelidonii</i>	2
Capparidaceae	<i>Cleome hassleriana</i> Chodat	1
Capparidaceae	<i>Cleome viscosa</i>	2
Capparidaceae	<i>Polanisia tenuifolia</i> Torr. and Gray	1, 2
Caprifoliaceae	<i>Lonicera etrusca</i>	2
Caryophyllaceae	<i>Dianthus caryophyllus</i>	2
Caryophyllaceae	<i>Dianthus chinensis</i>	2
Caryophyllaceae	<i>Gypsophila</i> sp.	2
Caryophyllaceae	<i>Vaccaria hispanica</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Celtidaceae	<i>Trema orientalis</i>	2
Chenopodiaceae	<i>Atriplex rhagodioides</i> F. MuelL.	1
Chenopodiaceae	<i>Chenopodium giganteum</i>	2
Chenopodiaceae	<i>Chenopodium quinoa</i>	2
Chrysobalanaceae	<i>Chrysobalanus orbicularis</i>	2
Cistaceae	<i>Helianthemum</i> sp.	2
Clusiaceae	<i>Hypericum androsaemum</i>	2
Clusiaceae	<i>Hypericum perforatum</i>	2
Clusiaceae	<i>Hypericum xylosteifolium</i>	2
Commelinaceae	<i>Commelina benghalensis</i>	2
Commelinaceae	<i>Tradescantia</i> sp.	1, 2
Convolvulaceae	<i>Convolvulus sabatius</i>	2
Convolvulaceae	<i>Ipomoea blepharosepala</i>	2
Convolvulaceae	<i>Ipomoea cairica</i>	2
Convolvulaceae	<i>Ipomoea carnea</i>	2
Convolvulaceae	<i>Ipomoea cordofana</i>	2
Convolvulaceae	<i>Ipomoea hederacea</i>	2
Convolvulaceae	<i>Ipomoea involucrata</i>	2
Convolvulaceae	<i>Ipomoea nil</i>	1, 2
Convolvulaceae	<i>Ipomoea phyllomega</i>	2
Convolvulaceae	<i>Ipomoea purga</i>	2
Convolvulaceae	<i>Ipomoea purpurea</i> (L.) Roth	1, 2
Convolvulaceae	<i>Ipomoea sagittata</i>	2
Convolvulaceae	<i>Ipomoea tricolor</i>	2
Convolvulaceae	<i>Jacquemontia tamnifolia</i>	2
Convolvulaceae	<i>Merremia quinquefolia</i>	2
Convolvulaceae	<i>Turbina corymbosa</i>	2
Costaceae	<i>Costus</i> sp.	1, 2
Cucurbitaceae	<i>Coccinia grandis</i>	2
Cucurbitaceae	<i>Cucumis anguria</i>	2
Cucurbitaceae	<i>Cucumis moschatus</i>	2
Cucurbitaceae	<i>Ecballium elaterium</i>	2
Cucurbitaceae	<i>Kedrostis africana</i>	1, 2
Cucurbitaceae	<i>Telfairia</i> sp.	2
Cucurbitaceae	<i>Trichosanthes dioica</i>	2
Dioscoreaceae	<i>Dioscorea batatas</i> Decne.	1
Ericaceae	<i>Arbutus menziesii</i> Pursh	1, 2
Ericaceae	<i>Vaccinium ashei</i> Reade	1
Ericaceae	<i>Vaccinium virgatum</i>	2
Euphorbiaceae	<i>Acalypha hispida</i>	2
Euphorbiaceae	<i>Acalypha indica</i>	2
Euphorbiaceae	<i>Acalypha marginata</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Euphorbiaceae	<i>Bridelia ferruginea</i>	2
Euphorbiaceae	<i>Chamaesyce blodgettii</i>	1, 2
Euphorbiaceae	<i>Chamaesyce hirta</i> (L.) Millsp.	1, 2
Euphorbiaceae	<i>Chamaesyce hypericifolia</i> (L.) Millsp.	1, 2
Euphorbiaceae	<i>Chamaesyce hyssopifolia</i> (L.) Small	1
Euphorbiaceae	<i>Chamaesyce maculata</i> (L.) Small	1, 2
Euphorbiaceae	<i>Chamaesyce pediculifera</i>	2
Euphorbiaceae	<i>Chamaesyce prostrata</i> (Ait.) Small	1, 2
Euphorbiaceae	<i>Chrozophora tinctoria</i>	2
Euphorbiaceae	<i>Codiaeum</i> sp.	1, 2
Euphorbiaceae	<i>Croton bonplandianus</i>	2
Euphorbiaceae	<i>Croton lobatus</i>	2
Euphorbiaceae	<i>Croton sparsiflorus</i>	2
Euphorbiaceae	<i>Euphorbia aegyptiaca</i>	2
Euphorbiaceae	<i>Euphorbia albomarginata</i>	1
Euphorbiaceae	<i>Euphorbia characias</i>	2
Euphorbiaceae	<i>Euphorbia convolvuloides</i>	2
Euphorbiaceae	<i>Euphorbia cyathophora</i>	2
Euphorbiaceae	<i>Euphorbia dendroides</i>	2
Euphorbiaceae	<i>Euphorbia falcata</i>	2
Euphorbiaceae	<i>Euphorbia lactea</i>	2
Euphorbiaceae	<i>Euphorbia lathyris</i>	2
Euphorbiaceae	<i>Euphorbia prostrata</i>	1
Euphorbiaceae	<i>Euphorbia trigona</i>	1, 2
Euphorbiaceae	<i>Jatropha curcas</i>	2
Euphorbiaceae	<i>Jatropha gossypifolia</i> L.	1, 2
Euphorbiaceae	<i>Jatropha multifida</i>	2
Euphorbiaceae	<i>Macaranga tanarius</i>	2
Euphorbiaceae	<i>Manihot aipi</i>	1
Euphorbiaceae	<i>Micrococca mercurialis</i>	2
Euphorbiaceae	<i>Phyllanthus maderaspatensis</i>	2
Euphorbiaceae	<i>Phyllanthus myrtifolius</i>	2
Euphorbiaceae	<i>Phyllanthus niruri</i>	2
Euphorbiaceae	<i>Phyllanthus tenellus</i> Roxb.	1, 2
Euphorbiaceae	<i>Trewia nudiflora</i>	2
Fabaceae	<i>Acacia koa</i>	2
Fabaceae	<i>Acacia nilotica</i>	2
Fabaceae	<i>Albizia lebbek</i>	2
Fabaceae	<i>Bauhinia purpurea</i>	2
Fabaceae	<i>Bauhinia racemosa</i>	2
Fabaceae	<i>Bauhinia tomentosa</i>	2
Fabaceae	<i>Bituminaria bituminosa</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Fabaceae	<i>Butea monosperma</i>	2
Fabaceae	<i>Cajanus cajan</i>	2
Fabaceae	<i>Calopogonium</i> sp.	2
Fabaceae	<i>Canavalia ensiformis</i>	2
Fabaceae	<i>Cassia fistula</i>	2
Fabaceae	<i>Cassia javanica</i>	2
Fabaceae	<i>Cassia obtusifolia</i>	2
Fabaceae	<i>Castanospermum australe</i>	2
Fabaceae	<i>Centrosema pubescens</i>	2
Fabaceae	<i>Cercis canadensis</i>	1, 2
Fabaceae	<i>Cicer arietinum</i>	2
Fabaceae	<i>Clitoria ternatea</i>	2
Fabaceae	<i>Crotalaria juncea</i>	2
Fabaceae	<i>Crotalaria mucronata</i>	1
Fabaceae	<i>Crotalaria pallida</i>	2
Fabaceae	<i>Crotalaria pycnostachya</i>	2
Fabaceae	<i>Cyamopsis tetragonoloba</i>	2
Fabaceae	<i>Desmodium intortum</i>	2
Fabaceae	<i>Desmodium triquetrum</i>	2
Fabaceae	<i>Desmodium velutinum</i>	2
Fabaceae	<i>Dolichos biflorus</i>	2
Fabaceae	<i>Dolichos lablab</i> L.	1
Fabaceae	<i>Erythrina stricta</i>	2
Fabaceae	<i>Erythrina variegata</i>	2
Fabaceae	<i>Glycine javanica</i>	2
Fabaceae	<i>Glycine tabacina</i>	2
Fabaceae	<i>Hardenbergia violacea</i>	2
Fabaceae	<i>Indigofera hirsuta</i>	2
Fabaceae	<i>Kennedia</i> sp.	2
Fabaceae	<i>Lathyrus clymenum</i>	2
Fabaceae	<i>Lens culinaris</i>	2
Fabaceae	<i>Lespedeza bicolor</i>	2
Fabaceae	<i>Lupinus hartwegii</i>	2
Fabaceae	<i>Lupinus perennis</i>	2
Fabaceae	<i>Macroptilium atropurpureum</i>	2
Fabaceae	<i>Macroptilium lathyroides</i>	2
Fabaceae	<i>Macrotyloma uniflorum</i>	2
Fabaceae	<i>Medicago lupulina</i>	2
Fabaceae	<i>Medicago polymorpha</i>	2
Fabaceae	<i>Melilotus indicus</i>	2
Fabaceae	<i>Millettia drastica</i>	2
Fabaceae	<i>Mucuna pruriens</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Fabaceae	<i>Neptunia oleracea</i>	2
Fabaceae	<i>Peltophorum dubium</i> (Spreng.) Taubert	1, 2
Fabaceae	<i>Phaseolus acutifolius</i>	2
Fabaceae	<i>Phaseolus acutifolius</i> Gray var. <i>acutifolius</i>	1
Fabaceae	<i>Phaseolus limensis</i> Macfady.	1
Fabaceae	<i>Phaseolus longepedunculatus</i>	2
Fabaceae	<i>Phaseolus lunatus</i> L.	1, 2
Fabaceae	<i>Piliostigma thonningii</i>	2
Fabaceae	<i>Platysepalum vanderystii</i>	2
Fabaceae	<i>Prosopis farcta</i>	2
Fabaceae	<i>Pterocarpus erinaceus</i>	2
Fabaceae	<i>Rhynchosia minima</i>	2
Fabaceae	<i>Senna alexandrina</i>	2
Fabaceae	<i>Senna occidentali</i>	2
Fabaceae	<i>Senna tora</i>	2
Fabaceae	<i>Sesbania bispinosa</i>	2
Fabaceae	<i>Sesbania exaltata</i>	2
Fabaceae	<i>Sesbania sesban</i>	2
Fabaceae	<i>Stylosanthes guianensis</i>	2
Fabaceae	<i>Tephrosia apollinea</i>	2
Fabaceae	<i>Tephrosia purpurea</i>	2
Fabaceae	<i>Teramnus uncinatus</i>	2
Fabaceae	<i>Trifolium alexandrinum</i>	2
Fabaceae	<i>Trigonella</i> sp.	2
Fabaceae	<i>Vicia cracca</i>	2
Fabaceae	<i>Vicia lens</i>	2
Fabaceae	<i>Vicia villosa</i>	2
Fabaceae	<i>Vigna aconitifolia</i> (Jacq.) Marechal	1, 2
Fabaceae	<i>Vigna angularis</i>	2
Fabaceae	<i>Vigna luteola</i>	2
Fabaceae	<i>Vigna mungo</i>	2
Fabaceae	<i>Vigna sesquipedalis</i>	2
Fabaceae	<i>Vigna sinensis</i>	2
Fabaceae	<i>Vigna subterranea</i>	2
Fabaceae	<i>Vigna umbellata</i>	2
Fabaceae	<i>Wisteria</i> sp.	1, 2
Fagaceae	<i>Lithocarpus densiflorus</i>	2
Fagaceae	<i>Quercus agrifolia</i>	1, 2
Fagaceae	<i>Quercus densiflora</i>	1
Flacourtiaceae	<i>Rawsonia lucida</i>	2
Gentianaceae	<i>Eustoma russellianum</i>	1, 2
Gentianaceae	<i>Exacum affine</i> Balf. f.	1, 2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Gentianaceae	<i>Irlbachia alata</i>	2
Gentianaceae	<i>Lisianthus</i> sp.	1
Geraniaceae	<i>Erodium</i> sp.	2
Geraniaceae	<i>Sarcocaulon crassicaule</i>	2
Gesneriaceae	<i>Sinningia</i> sp.	2
Gesneriaceae	<i>Titanotrichum oldhamii</i>	2
Globulariaceae	<i>Globularia</i> sp.	2
Grossulariaceae	<i>Ribes cynosbati</i>	2
Grossulariaceae	<i>Ribes uva-crispa</i>	2
Guttiferae	<i>Hypericum hypericoides</i> (L.) Crantz	1, 2
Guttiferae	<i>Psorospermum corymbiferum</i>	2
Haloragaceae	<i>Myriophyllum</i> sp.	1
Hamamelidaceae	<i>Liquidambar styraciflua</i>	2
Hamamelidaceae	<i>Liquidambar styraciflua</i> L.	1
Iridaceae	<i>Gladiolus hortulanus</i> Bailey	1, 2
Lamiaceae	<i>Ajuga pyramidalis</i>	2
Lamiaceae	<i>Ajuga reptans</i>	1, 2
Lamiaceae	<i>Anisomeles indica</i>	2
Lamiaceae	<i>Callicarpa</i> sp.	2
Lamiaceae	<i>Clerodendrum Inerme</i>	2
Lamiaceae	<i>Elsholtzia ciliata</i>	2
Lamiaceae	<i>Gmelina</i> sp.	2
Lamiaceae	<i>Holmskioldia sanguinea</i>	2
Lamiaceae	<i>Lamium purpureum</i>	2
Lamiaceae	<i>Lavandula</i> sp.	2
Lamiaceae	<i>Leucas ciliata</i>	2
Lamiaceae	<i>Leucas stelligera</i>	2
Lamiaceae	<i>Mentha javanica</i>	1
Lamiaceae	<i>Mentha longifolia</i>	2
Lamiaceae	<i>Mentha spicata</i>	1, 2
Lamiaceae	<i>Mentha suaveolens</i> Ehrh.	1, 2
Lamiaceae	<i>Mentha piperita</i> L.	1, 2
Lamiaceae	<i>Nepeta ruderalis</i>	2
Lamiaceae	<i>Ocimum gracile</i>	2
Lamiaceae	<i>Ocimum sanctum</i>	2
Lamiaceae	<i>Origanum majorana</i>	1
Lamiaceae	<i>Origanum vulgare</i>	2
Lamiaceae	<i>Phlomis anisodonta</i>	2
Lamiaceae	<i>Pogostemon</i> sp.	2
Lamiaceae	<i>Rosmarinus officinalis</i> L.	1, 2
Lamiaceae	<i>Salvia officinalis</i> L.	1, 2
Lamiaceae	<i>Salvia repens</i>	1

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Lamiaceae	<i>Thymus vulgaris</i>	1, 2
Lamiaceae	<i>Vitex agnus-castus</i>	2
Lamiaceae	<i>Vitex keniensis</i>	2
Lamiaceae	<i>Vitex negundo</i>	2
Lauraceae	<i>Cinnamomum camphora</i>	2
Lauraceae	<i>Umbellularia californica</i> (Hook. and Arn.) Nutt.	1, 2
Liliaceae	<i>Allium cepa</i>	2
Liliaceae	<i>Asparagus densiflorus</i> (Kunth) Jessop	1, 2
Liliaceae	<i>Leucojum aestivum</i>	2
Liliaceae	<i>Pleomele</i> sp.	1
Linaceae	<i>Linum usitatissimum</i>	2
Linaceae	<i>Reinwardtia trigyna</i>	2
Loganiaceae	<i>Gelsemium sempervirens</i>	2
Lythraceae	<i>Cuphea hyssopifolia</i> HBK	1, 2
Magnoliaceae	<i>Liriodendron tulipifera</i> L.	1, 2
Malvaceae	<i>Abelmoschus esculentus</i> (L.) Moench	1,2
Malvaceae	<i>Abutilon bidentatum</i>	2
Malvaceae	<i>Abutilon figarianum</i>	2
Malvaceae	<i>Abutilon glaucum</i>	2
Malvaceae	<i>Abutilon grandiflorum</i>	2
Malvaceae	<i>Abutilon zanzibaricum</i>	2
Malvaceae	<i>Alcea rosea</i>	2
Malvaceae	<i>Althaea officinalis</i>	2
Malvaceae	<i>Alyogyne</i> sp.	2
Malvaceae	<i>Gossypium arboreum</i>	2
Malvaceae	<i>Gossypium herbaceum</i>	2
Malvaceae	<i>Gossypium thurberi</i>	2
Malvaceae	<i>Hibiscus cameronii</i>	2
Malvaceae	<i>Hibiscus cannabinus</i>	2
Malvaceae	<i>Hibiscus diversifolius</i>	2
Malvaceae	<i>Hibiscus furcellatus</i> Desr.	1, 2
Malvaceae	<i>Hibiscus heterophyllus</i>	2
Malvaceae	<i>Hibiscus lasiocarpus</i>	1
Malvaceae	<i>Hibiscus moscheutos</i> L.	1, 2
Malvaceae	<i>Hibiscus ternifoliolus</i>	2
Malvaceae	<i>Malva nicaensis</i>	2
Malvaceae	<i>Malva parviflora</i>	2
Malvaceae	<i>Malvastrum coromandelianum</i>	2
Malvaceae	<i>Malvaviscus arboreus</i>	2
Malvaceae	<i>Malvella leprosa</i>	2
Malvaceae	<i>Sida acuta</i> Burm. f.	1, 2
Malvaceae	<i>Sida alba</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Malvaceae	<i>Sida carpinifolia</i>	2
Malvaceae	<i>Sida cordifolia</i>	2
Malvaceae	<i>Sida fallax</i>	2
Malvaceae	<i>Sida grewioides</i>	2
Malvaceae	<i>Sida veronicaefolia</i>	2
Malvaceae	<i>Sphaeralcea coccinea</i>	2
Malvaceae	<i>Wissadula amplissima</i>	2
Mayacaceae	<i>Mayaca fluviatilis</i>	2
Melastomataceae	<i>Tibouchina</i> sp.	1, 2
Menispermaceae	<i>Stephania japonica</i>	2
Moraceae	<i>Ficus benjamina</i> L.	1, 2
Moraceae	<i>Ficus elastica</i> Roxb. ex Hornem.	1, 2
Moraceae	<i>Ficus palmata</i>	2
Moraceae	<i>Ficus sycomorus</i>	2
Moraceae	<i>Maclura aurantiaca</i>	2
Moraceae	<i>Morus australis</i>	2
Moringaceae	<i>Moringa oleifera</i> L.	1, 2
Musaceae	<i>Musa paradisiaca</i>	2
Myrtaceae	<i>Callistemon</i> sp.	2
Myrtaceae	<i>Eucalyptus grandis</i>	2
Myrtaceae	<i>Eugenia</i> sp.	2
Myrtaceae	<i>Metrosideros</i> sp.	2
Myrtaceae	<i>Myrtus communis</i>	2
Myrtaceae	<i>Myrtus tarentina</i>	2
Myrtaceae	<i>Syzygium cumini</i>	2
Myrtaceae	<i>Syzygium malaccense</i>	2
Nyctaginaceae	<i>Boerhavia diffusa</i>	2
Oleaceae	<i>Forsythia suspensa</i>	2
Oleaceae	<i>Jasminum humile</i>	2
Oleaceae	<i>Jasminum officinale</i>	2
Oleaceae	<i>Ligustrum japonicum</i> Thunb.	1, 2
Oleaceae	<i>Ligustrum vulgare</i>	2
Oleaceae	<i>Olea europaea</i>	2
Onagraceae	<i>Fuchsia</i> sp.	1, 2
Onagraceae	<i>Gaura lindheimeri</i>	2
Onagraceae	<i>Ludwigia arcuata</i>	2
Onagraceae	<i>Ludwigia palustris</i>	1, 2
Orchidaceae	<i>Dendrobium</i> sp.	2
Oxalidaceae	<i>Oxalis deppei</i>	2
Pedaliaceae	<i>Josephinia eugeniae</i>	2
Pedaliaceae	<i>Uncarina grandidieri</i> (Baill.) Stapf	1, 2
Phytolaccaceae	<i>Rivina humilis</i> L.	1, 2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Piperaceae	<i>Piper sarmentosum</i>	2
Plumbaginaceae	<i>Plumbago auriculata</i> Lam.	1, 2
Plumbaginaceae	<i>Plumbago europaea</i>	2
Poaceae	<i>Coix lacryma-jobi</i>	2
Poaceae	<i>Hemarthria compressa</i>	2
Poaceae	<i>Oplismenus burmannii</i>	2
Poaceae	<i>Oryza sativa</i>	2
Poaceae	<i>Panicum adspersum</i>	1
Poaceae	<i>Pennisetum americanum</i>	2
Poaceae	<i>Saccharum officinarum</i>	2
Poaceae	<i>Sorghum bicolor</i>	2
Poaceae	<i>Sorghum halepense</i>	2
Poaceae	<i>Urochloa adspersa</i>	2
Poaceae	<i>Zea mays</i>	2
Polemoniaceae	<i>Phlox drummondii</i>	2
Polygalaceae	<i>Polygala polygama</i> Walt.	1, 2
Polygonaceae	<i>Antigonon leptopus</i>	2
Polygonaceae	<i>Persicaria maculosa</i>	2
Polygonaceae	<i>Persicaria odorata</i>	2
Polygonaceae	<i>Rumex obtusifolius</i>	2
Pontederiaceae	<i>Heteranthera</i> sp.	2
Primulaceae	<i>Lysimachia</i> sp.	1, 2
Primulaceae	<i>Primula vulgaris</i>	2
Proteaceae	<i>Helicia cochinchinensis</i>	2
Ranunculaceae	<i>Clematis ligusticifolia</i>	1, 2
Ranunculaceae	<i>Clematis</i> sp.	2
Ranunculaceae	<i>Ranunculus langsdorfii</i>	2
Ranunculaceae	<i>Ranunculus muricatus</i>	2
Rhamnaceae	<i>Frangula californica</i>	2
Rhamnaceae	<i>Rhamnus californica</i> Eschsch. ssp. <i>californica</i>	1
Rhamnaceae	<i>Rhamnus crocea</i> Nutt.	1, 2
Rhamnaceae	<i>Ziziphus mauritiana</i>	2
Rosaceae	<i>Crataegus microphylla</i>	1
Rosaceae	<i>Heteromeles arbutifolia</i> (Lindl.) M. Roemer	1
Rosaceae	<i>Heteromeles salicifolia</i>	2
Rosaceae	<i>Potentilla</i> sp.	2
Rosaceae	<i>Pyrus calleryana</i>	2
Rosaceae	<i>Pyrus communis</i>	2
Rosaceae	<i>Pyrus mamorensis</i>	2
Rosaceae	<i>Rosa gallica</i>	2
Rubiaceae	<i>Bouvardia</i> sp.	2
Rubiaceae	<i>Coprosma repens</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Rubiaceae	<i>Hedyotis corymbosa</i>	1, 2
Rubiaceae	<i>Ixora coccinea</i> L.	1, 2
Rubiaceae	<i>Morinda tinctoria</i>	2
Rutaceae	<i>Citrus hystrix</i>	2
Rutaceae	<i>Citrus paradisi</i> Macfad.	1
Rutaceae	<i>Poncirus trifoliata</i> (L.) Raf.	1, 2
Rutaceae	<i>Ruta graveolens</i>	1
Salicaceae	<i>Salix</i> sp.	2
Sapindaceae	<i>Nephelium lappaceum</i>	2
Sapotaceae	<i>Chrysophyllum</i> sp.	2
Saururaceae	<i>Saururus</i> sp.	2
Saxifragaceae	<i>Tolmiea menziesii</i>	2
Scrophulariaceae	<i>Bacopa caroliniana</i>	2
Scrophulariaceae	<i>Bacopa monnieri</i>	2
Scrophulariaceae	<i>Capraria biflora</i>	2
Scrophulariaceae	<i>Diascia</i> sp.	2
Scrophulariaceae	<i>Limnophila chinensis</i>	2
Scrophulariaceae	<i>Limnophila gratissima</i>	2
Scrophulariaceae	<i>Mecardonia acuminata</i> (Walt.) Small	1, 2
Scrophulariaceae	<i>Parahebe catarractae</i>	2
Scrophulariaceae	<i>Rhinanthus nasutus</i>	1
Scrophulariaceae	<i>Scoparia dulcis</i>	2
Scrophulariaceae	<i>Torenia</i> sp.	2
Scrophulariaceae	<i>Veronica spicata</i>	2
Scrophulariaceae	<i>Zaluzianskya ovata</i>	2
Solanaceae	<i>Atropa belladonna</i>	2
Solanaceae	<i>Brugmansia suaveolens</i>	2
Solanaceae	<i>Brugmansia versicolor</i>	1, 2
Solanaceae	<i>Calibrachoa</i> sp.	2
Solanaceae	<i>Datura wrightii</i>	2
Solanaceae	<i>Hyoscyamus desertorum</i>	2
Solanaceae	<i>Hyoscyamus niger</i>	2
Solanaceae	<i>Lycopersicon pennellii</i>	2
Solanaceae	<i>Lycopersicon pimpinellifolium</i>	2
Solanaceae	<i>Nicandra physalodes</i>	2
Solanaceae	<i>Nicotiana benthamiana</i>	2
Solanaceae	<i>Nicotiana glauca</i>	2
Solanaceae	<i>Nicotiana glutinosa</i>	2
Solanaceae	<i>Nicotiana plumbaginifolia</i>	2
Solanaceae	<i>Nicotiana rustica</i>	2
Solanaceae	<i>Petunia integrifolia</i>	2
Solanaceae	<i>Physalis acutifolia</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Solanaceae	<i>Physalis heterophylla</i>	2
Solanaceae	<i>Physalis ixocarpa</i>	1
Solanaceae	<i>Physalis minima</i>	2
Solanaceae	<i>Physalis peruviana</i>	2
Solanaceae	<i>Physalis pubescens</i>	2
Solanaceae	<i>Solanum aculeatissimum</i>	2
Solanaceae	<i>Solanum dubium</i>	2
Solanaceae	<i>Solanum elaeagnifolium</i>	2
Solanaceae	<i>Solanum erianthum</i>	2
Solanaceae	<i>Solanum jasminoides</i> Paxton	1, 2
Solanaceae	<i>Solanum macrocarpon</i>	2
Solanaceae	<i>Solanum torvum</i> Sw.	1, 2
Solanaceae	<i>Solanum villosum</i>	2
Solanaceae	<i>Solanum xanthocarpum</i>	2
Sterculiaceae	<i>Glossostemon bruguieri</i>	2
Sterculiaceae	<i>Guazuma tomentosa</i>	2
Sterculiaceae	<i>Theobroma cacao</i>	2
Thymeliaceae	<i>Daphne gnidium</i>	2
Tiliaceae	<i>Corchorus acutangulus</i>	2
Tiliaceae	<i>Corchorus aestuans</i>	2
Tiliaceae	<i>Corchorus capsularis</i>	2
Tiliaceae	<i>Corchorus trilocularis</i>	2
Tiliaceae	<i>Grewia asiatica</i>	2
Tiliaceae	<i>Sparrmannia</i> sp.	2
Tiliaceae	<i>Triumfetta rhomboidea</i>	2
Tropaeolaceae	<i>Tropaeolum majus</i>	2
Turneraceae	<i>Turnera ulmifolia</i>	1, 2
Ulmaceae	<i>Celtis australis</i>	2
Ulmaceae	<i>Ulmus minor</i>	2
Ulmaceae	<i>Ulmus parvifolia</i> Jacq.	1, 2
Ulmaceae	<i>Zelkova serrata</i> (Thunb.) Mak.	1, 2
Urticaceae	<i>Laportea aestuans</i> (L.) Chew	1, 2
Urticaceae	<i>Oreocnide frutescens</i>	2
Urticaceae	<i>Pilea microphylla</i> (L.) Liebm.	1, 2
Valerianaceae	<i>Valeriana officinalis</i>	2
Verbenaceae	<i>Aloysia triphylla</i>	2
Verbenaceae	<i>Clerodendrum infortunatum</i>	2
Verbenaceae	<i>Clerodendrum splendens</i>	2
Verbenaceae	<i>Clerodendrum villosum</i>	2
Verbenaceae	<i>Duranta erecta</i>	2
Verbenaceae	<i>Glandularia maritima</i> (Small) Small	1, 2
Verbenaceae	<i>Lippia geminata</i>	2

Family	Species	Ref.
References - 1: Evans (2007); 2: DAF-GWA, (2008)		
Verbenaceae	<i>Lippia micromera</i>	2
Verbenaceae	<i>Lippia micromera</i> Schauer var. <i>helleri</i> (Britt.) Mold.	1
Verbenaceae	<i>Nyctanthes arbor-tristis</i>	2
Verbenaceae	<i>Phyla canescens</i>	2
Verbenaceae	<i>Verbena bonariensis</i>	2
Verbenaceae	<i>Verbena maritima</i>	1
Verbenaceae	<i>Verbena officinalis</i>	2
Verbenaceae	<i>Verbena hybrida</i> Voss	1
Violaceae	<i>Viola tricolor</i>	2
Zingiberaceae	<i>Elettaria cardamomum</i>	2
Zingiberaceae	<i>Globba</i> sp.	2

Table B.4: Top twenty host families

Abd-Rabou and Simmons (2010)	Bayhan et al. (2006b)	DAF-GWA, (2008)	Evans (2007)	Li et al. (2011a)
Asteraceae	Leguminosae	Leguminosae	Asteraceae	Asteraceae
Leguminosae	Solanaceae	Asteraceae	Euphorbiaceae	Leguminosae
Malvaceae	Malvaceae	Solanaceae	Leguminosae	Cruciferae
Cucurbitaceae	Asteraceae	Malvaceae	Lamiaceae	Solanaceae
Euphorbiaceae	Euphorbiaceae	Euphorbiaceae	Solanaceae	Cucurbitaceae
Solanaceae	Labiaceae	Lamiaceae	Malvaceae	Rosaceae
Brassicaceae	Amaranthaceae	Acanthaceae	Acanthaceae	Euphorbiaceae
Chenopodiaceae	Brassicaceae	Cucurbitaceae	Araceae	Amaranthaceae
Rutaceae	Nyctaginaceae	Amaranthaceae	Rutaceae	Malvaceae
Amaranthaceae	Polygonaceae	Convolvulaceae	Apocynaceae	Convolvulaceae
Verbenaceae	Rosaceae	Araceae	Cucurbitaceae	Oleaceae
Capparidaceae	Convolvulaceae	Verbenaceae	Verbenaceae	Araceae
Lamiaceae	Cucurbitaceae	Scrophulariaceae	Amaranthaceae	Lamiaceae
Rosaceae	Caprifoliaceae	Brassicaceae	Brassicaceae	Magnoliaceae
Rubiaceae	Cistaceae	Rosaceae	Rubiaceae	Apocynaceae
Vitaceae	Rutaceae	Poaceae	Moraceae	Liliaceae
Aristolochiaceae	Bignoniaceae	Moraceae	Convolvulaceae	Moraceae
Asclepiadaceae	Capparidaceae	Myrtaceae	Ericaceae	Rutaceae
Boraginaceae	Chenopodiaceae	Oleaceae	Gentianaceae	Verbenaceae
Graminae	Juglandaceae	Apocynaceae	Myrtaceae	Acanthaceae

Note: Families ranked according to the numbers of species. The grey boxes correspond to 50 % of the total species listed.

4.1. Notes on the host plants for *B. tabaci*

Tables B.1, B.2, B.3 and B.4 were compiled from six publications, differing from each other in data accuracy. The following notes provide a brief introduction to these publications.

Abd-Rabou and Simmons (2010)

"The B and Q biotypes are both found on cultivated and wild plants in Egypt, although the Q biotype is only known to occur in the Nile Delta region (...) A field survey was conducted on the reproductive host plant species of the *Bemisia tabaci* (Gennadius) complex throughout Egypt. Infested plants were collected during each month of the year. *Bemisia tabaci* completed its development on 118 species of plants in 79 genera belonging to 28 families."

Simmons et al. (2008)

"An open-choice screening experiment was conducted with B-biotype *B. tabaci* on a diverse collection of crops, weeds, and other indigenous plant species. Five of the plant species were further evaluated in choice or no-choice tests in the laboratory. The results reveal 49 new reproductive host plant species for *B. tabaci*. (...) All species that served as hosts were acceptable for feeding, oviposition, and development to the adult stage by *B. tabaci*." This represents a total of 49 spp., belonging to 11 families, 30 new species.

DAF-GWA, (2008)

905 species belonging to 115 families. No details regarding data accuracy.

Bayhan et al., (2006b)

"From the southern Turkey collections, (B biotype) *B. tabaci* was found to colonize (to reproduce successfully on) 152 species from 43 plant families."

Evans (2007)

"The following host plant list was extracted from the Whitefly Taxonomic and Ecological database and edited to make it more readable."

Li et al. (2011a)

"Potential host plants and natural enemies of *B. tabaci* in the south, southeast, middle, north and northwest of China were investigated during the last decade. In total 361 plant species from 89 families were recorded." Field observations with records on insect density (4th grade: average number of *B. tabaci* nymphs and pupae > 50/10 cm²; 3rd grade: 31–50 /10 cm²; 2nd grade: 11–30/10 cm²; 1st grade: ≤ 10/10 cm²).

2. *B. tabaci* transmitted viruses

Table B.5: *B. tabaci*-transmitted viruses

Family	Genus	Species
<i>Geminiviridae</i>	Begomovirus	Abutilon mosaic virus
<i>Geminiviridae</i>	Begomovirus	African cassava mosaic virus
<i>Geminiviridae</i>	Begomovirus	Ageratum enation virus
<i>Geminiviridae</i>	Begomovirus	Ageratum leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Ageratum yellow vein Hualian virus
<i>Geminiviridae</i>	Begomovirus	Ageratum yellow vein Sri Lanka virus
<i>Geminiviridae</i>	Begomovirus	Ageratum yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Alternanthera yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Bean calico mosaic virus
<i>Geminiviridae</i>	Begomovirus	Bean dwarf mosaic virus
<i>Geminiviridae</i>	Begomovirus	Bean golden mosaic virus
<i>Geminiviridae</i>	Begomovirus	<i>Bean golden yellow mosaic virus</i>
<i>Geminiviridae</i>	Begomovirus	Bhendi yellow vein mosaic virus
<i>Geminiviridae</i>	Begomovirus	Bitter gourd yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Boerhavia yellow spot virus
<i>Geminiviridae</i>	Begomovirus	Cabbage leaf curl Jamaica virus
<i>Geminiviridae</i>	Begomovirus	Cabbage leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Chayote yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Chilli leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Chino del tomate virus
<i>Geminiviridae</i>	Begomovirus	Clerodendron golden mosaic virus
<i>Geminiviridae</i>	Begomovirus	Corchorus golden mosaic virus
<i>Geminiviridae</i>	Begomovirus	Corchorus yellow spot virus
<i>Geminiviridae</i>	Begomovirus	Corchorus yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Cotton leaf crumple virus
<i>Geminiviridae</i>	Begomovirus	Cotton leaf curl Alabad virus
<i>Geminiviridae</i>	Begomovirus	Cotton leaf curl Bangalore virus
<i>Geminiviridae</i>	Begomovirus	Cotton leaf curl Gezira virus
<i>Geminiviridae</i>	Begomovirus	Cotton leaf curl Kokhran virus
<i>Geminiviridae</i>	Begomovirus	Cotton leaf curl Multan virus
<i>Geminiviridae</i>	Begomovirus	Cowpea golden mosaic virus
<i>Geminiviridae</i>	Begomovirus	Croton yellow vein mosaic virus
<i>Geminiviridae</i>	Begomovirus	Cucurbit leaf crumple virus

Family	Genus	Species
<i>Geminiviridae</i>	Begomovirus	Desmodium leaf distortion virus
<i>Geminiviridae</i>	Begomovirus	Dicliptera yellow mottle Cuba virus
<i>Geminiviridae</i>	Begomovirus	Dicliptera yellow mottle virus
<i>Geminiviridae</i>	Begomovirus	Dolichos yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	East African cassava mosaic Cameroon virus
<i>Geminiviridae</i>	Begomovirus	East African cassava mosaic Kenya virus
<i>Geminiviridae</i>	Begomovirus	East African cassava mosaic Malawi virus
<i>Geminiviridae</i>	Begomovirus	East African cassava mosaic virus
<i>Geminiviridae</i>	Begomovirus	East African cassava mosaic Zanzibar virus
<i>Geminiviridae</i>	Begomovirus	Erectites yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Eupatorium yellow vein mosaic virus
<i>Geminiviridae</i>	Begomovirus	Eupatorium yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Euphorbia leaf curl Guangxi virus
<i>Geminiviridae</i>	Begomovirus	Euphorbia leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Euphorbia mosaic virus
<i>Geminiviridae</i>	Begomovirus	Hollyhock leaf crumple virus
<i>Geminiviridae</i>	Begomovirus	Honeysuckle yellow vein Kagoshima virus
<i>Geminiviridae</i>	Begomovirus	Honeysuckle yellow vein mosaic virus
<i>Geminiviridae</i>	Begomovirus	Honeysuckle yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Horsegram yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Indian cassava mosaic virus
<i>Geminiviridae</i>	Begomovirus	Ipomoea yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Kudzu mosaic virus
<i>Geminiviridae</i>	Begomovirus	Lindernia anagallis yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Ludwigia yellow vein Vietnam virus
<i>Geminiviridae</i>	Begomovirus	Ludwigia yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Luffa yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Macroptilium mosaic Puerto Rico virus
<i>Geminiviridae</i>	Begomovirus	Macroptilium yellow mosaic Florida virus
<i>Geminiviridae</i>	Begomovirus	Macroptilium yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Malvastrum leaf curl Guangdong virus
<i>Geminiviridae</i>	Begomovirus	Malvastrum leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Malvastrum yellow leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Malvastrum yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Malvastrum yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Malvastrum yellow vein Yunnan virus

Family	Genus	Species
<i>Geminiviridae</i>	Begomovirus	Melon chlorotic leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Merremia mosaic virus
<i>Geminiviridae</i>	Begomovirus	Mesta yellow vein mosaic virus
<i>Geminiviridae</i>	Begomovirus	Mimosa yellow leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Mungbean yellow mosaic India virus
<i>Geminiviridae</i>	Begomovirus	Mungbean yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Okra yellow crinkle virus
<i>Geminiviridae</i>	Begomovirus	Okra yellow mosaic Mexico virus
<i>Geminiviridae</i>	Begomovirus	Okra yellow mottle Iguala virus
<i>Geminiviridae</i>	Begomovirus	Okra yellow vein mosaic virus
<i>Geminiviridae</i>	Begomovirus	Papaya leaf curl China virus
<i>Geminiviridae</i>	Begomovirus	Papaya leaf curl Guandong virus
<i>Geminiviridae</i>	Begomovirus	Papaya leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Pedilanthus leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Pepper golden mosaic virus
<i>Geminiviridae</i>	Begomovirus	Pepper huasteco yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Pepper leaf curl Bangladesh virus
<i>Geminiviridae</i>	Begomovirus	Pepper leaf curl Lahore virus
<i>Geminiviridae</i>	Begomovirus	Pepper leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Pepper yellow leaf curl Indonesia virus
<i>Geminiviridae</i>	Begomovirus	Pepper yellow vein Mali virus
<i>Geminiviridae</i>	Begomovirus	Potato yellow mosaic Panama virus
<i>Geminiviridae</i>	Begomovirus	Potato yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Pumpkin yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Radish leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Rhynchosia golden mosaic Sinaloa virus
<i>Geminiviridae</i>	Begomovirus	Rhynchosia golden mosaic virus
<i>Geminiviridae</i>	Begomovirus	Senecio yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Sida golden mosaic Costa Rica virus
<i>Geminiviridae</i>	Begomovirus	Sida golden mosaic Florida virus
<i>Geminiviridae</i>	Begomovirus	Sida golden mosaic Honduras virus
<i>Geminiviridae</i>	Begomovirus	Sida golden mosaic virus
<i>Geminiviridae</i>	Begomovirus	Sida golden yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Sida leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Sida micrantha mosaic virus
<i>Geminiviridae</i>	Begomovirus	Sida mottle virus

Family	Genus	Species
<i>Geminiviridae</i>	Begomovirus	Sida yellow mosaic China virus
<i>Geminiviridae</i>	Begomovirus	Sida yellow mosaic virus
<i>Geminiviridae</i>	Begomovirus	Sida yellow mosaic Yucatan virus
<i>Geminiviridae</i>	Begomovirus	Sida yellow vein Madurai virus
<i>Geminiviridae</i>	Begomovirus	Sida yellow vein Vietnam virus
<i>Geminiviridae</i>	Begomovirus	Sida yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Siegesbeckia yellow vein Guangxi virus
<i>Geminiviridae</i>	Begomovirus	Siegesbeckia yellow vein virus
<i>Geminiviridae</i>	Begomovirus	South African cassava mosaic virus
<i>Geminiviridae</i>	Begomovirus	Soybean blistering mosaic virus
<i>Geminiviridae</i>	Begomovirus	Soybean crinkle leaf virus
<i>Geminiviridae</i>	Begomovirus	Spilanthus yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Squash leaf curl China virus
<i>Geminiviridae</i>	Begomovirus	Squash leaf curl Philippines virus
<i>Geminiviridae</i>	Begomovirus	Squash leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Squash leaf curl Yunnan virus
<i>Geminiviridae</i>	Begomovirus	Squash mild leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Sri Lankan cassava mosaic virus
<i>Geminiviridae</i>	Begomovirus	Stachytarpheta leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Sweet potato leaf curl Canary virus
<i>Geminiviridae</i>	Begomovirus	Sweet potato leaf curl China virus
<i>Geminiviridae</i>	Begomovirus	Sweet potato leaf curl Georgia virus
<i>Geminiviridae</i>	Begomovirus	Sweet potato leaf curl Lanzarote virus
<i>Geminiviridae</i>	Begomovirus	Sweet potato leaf curl Spain virus
<i>Geminiviridae</i>	Begomovirus	Sweet potato leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Tobacco curly shoot virus
<i>Geminiviridae</i>	Begomovirus	Tobacco leaf curl Cuba virus
<i>Geminiviridae</i>	Begomovirus	Tobacco leaf curl Japan virus
<i>Geminiviridae</i>	Begomovirus	Tobacco leaf curl Yunnan virus
<i>Geminiviridae</i>	Begomovirus	Tobacco leaf curl Zimbabwe virus
<i>Geminiviridae</i>	Begomovirus	Tomato chino La Paz virus
<i>Geminiviridae</i>	Begomovirus	Tomato chlorotic mottle virus
<i>Geminiviridae</i>	Begomovirus	Tomato curly stunt virus
<i>Geminiviridae</i>	Begomovirus	Tomato golden mosaic virus
<i>Geminiviridae</i>	Begomovirus	Tomato golden mottle virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Arusha virus

Family	Genus	Species
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Bangalore virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Bangladesh virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl China virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Comoros virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Guangdong virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Guangxi virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Gujarat virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Hsinchu virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Java virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Joydebpur virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Karnataka virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Kerala virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Laos virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Madagascar virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Malaysia virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Mali virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Mayotte virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl New Delhi virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Philippines virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Pune virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Seychelles virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Sinaloa virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Sri Lanka virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Sudan virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Taiwan virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Uganda virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl Vietnam virus
<i>Geminiviridae</i>	Begomovirus	Tomato leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Tomato mild yellow leaf curl Aragua virus
<i>Geminiviridae</i>	Begomovirus	Tomato mosaic Havana virus
<i>Geminiviridae</i>	Begomovirus	Tomato mottle Taino virus
<i>Geminiviridae</i>	Begomovirus	Tomato mottle virus
<i>Geminiviridae</i>	Begomovirus	Tomato rugose mosaic virus
<i>Geminiviridae</i>	Begomovirus	Tomato severe leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Tomato severe rugose virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl Axarquia virus

Family	Genus	Species
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl China virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl Guangdong virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl Indonesia virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl Kanchanaburi virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl Malaga virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl Mali virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl Sardinia virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl Thailand virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl Vietnam virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow margin leaf curl virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow spot virus
<i>Geminiviridae</i>	Begomovirus	Tomato yellow vein streak virus
<i>Geminiviridae</i>	Begomovirus	Vernonia yellow vein virus
<i>Geminiviridae</i>	Begomovirus	Watermelon chlorotic stunt virus
<i>Closteroviridae</i>	Crinivirus	Bean yellow disorder virus
<i>Closteroviridae</i>	Crinivirus	Blackberry yellow vein-associated virus
<i>Closteroviridae</i>	Crinivirus	Cucurbit yellow stunting disorder virus
<i>Closteroviridae</i>	Crinivirus	Lettuce chlorosis virus
<i>Closteroviridae</i>	Crinivirus	<i>Lettuce infectious yellows virus</i>
<i>Closteroviridae</i>	Crinivirus	Strawberry pallidosis-associated virus
<i>Closteroviridae</i>	Crinivirus	Sweet potato chlorotic stunt virus
<i>Closteroviridae</i>	Crinivirus	Tomato chlorosis virus
<i>Potyviridae</i>	Ipomovirus	Cassava brown streak virus
<i>Potyviridae</i>	Ipomovirus	Cucumber vein yellowing virus
<i>Potyviridae</i>	Ipomovirus	Squash vein yellowing virus
<i>Potyviridae</i>	Ipomovirus	<i>Sweet potato mild mottle virus</i>
<i>Potyviridae</i>	Ipomovirus	Ugandan cassava brown streak virus
<i>Secoviridae</i>	Torradovirus	Tomato marchitez virus
<i>Secoviridae</i>	Torradovirus	<i>Tomato torrado virus</i>
<i>Betaflexiviridae</i>	Carlavirus	Cowpea mild mottle virus
<i>Betaflexiviridae</i>	Carlavirus	Melon yellowing-associated virus

Note: According to the ICTV, on line, Master Species list 2011. The names of the type species are in italics

Table B.6: Whitefly-transmitted begomoviruses infecting tomato

Species name (acronym)	Occurrence	References
<i>Ageratum enation virus</i> (AEV)	India	NCBI, on line - Reference Sequence: JX436472.1
<i>Ageratum yellow vein Hualian virus</i> (AYVHuV)	Taiwan	NCBI, on line - Reference Sequence: NC_010812.1
<i>Ageratum yellow vein virus</i> (AYVV)	Indonesia	Kon et al. (2006)
<i>Chino del tomate virus</i> (CdTV)	Mexico, Nicaragua, USA	Polston and Anderson (1997)
<i>Merremia mosaic virus</i> (MerMV)	Puerto Rico	NCBI, on line - Reference Sequence: DQ644557.1
<i>Papaya leaf curl China virus</i> (PaLCuCNV)	China	NCBI, on line - Reference Sequence: FN297834.1
<i>Papaya leaf curl virus</i> (PaLCuV)	India, Panama	ICTV (2011)
<i>Pepper golden mosaic virus</i> (PepGMV)	Costa Rica, Guatemala, Mexico, USA	Polston and Anderson (1997)
<i>Pepper huasteco yellow vein virus</i> (PHYVV)	Mexico, USA	Polston and Anderson (1997)
<i>Potato yellow mosaic Panama virus</i> (PYMPV)	Panama	ICTV (2011)
Potato yellow mosaic Trinidad virus (PYMTTV)	Trinidad and Tobago	Polston and Anderson (1997)
<i>Potato yellow mosaic virus</i> (PYMV)	Dominican Republic, Guadeloupe, Martinique, Puerto Rico, Venezuela	Polston and Anderson (1997)
<i>Tobacco leaf curl Japan virus</i> (TbLCJV)	Japan	ICTV (2011)
<i>Tomato chino La Paz virus</i> (ToChLPV)	Mexico	ICTV (2011)
<i>Tomato chlorotic mottle virus</i> (ToCMoV)	Brazil	ICTV (2011)
Tomato common mosaic virus (ToCMV)	Brazil	Castillo-Urquiza et al. (2008)
<i>Tomato curly stunt virus</i> (ToCSV)	South Africa	ICTV (2011)
<i>Tomato golden mosaic virus</i> (TGMV)	Brazil	ICTV (2011)
<i>Tomato golden mottle virus</i> (ToGMoV)	Guatemala	ICTV (2011)
Tomato leaf curl Antsiranana virus (ToLCAnV)	Madagascar	NCBI, on line - Reference Sequence: AM701766
<i>Tomato leaf curl Arusha virus</i> (ToLCArV)	Tanzania	NCBI, on line - Reference Sequence: NC_009030
<i>Tomato leaf curl Bangalore virus</i> (ToLCBaV)	India	ICTV (2011)
<i>Tomato leaf curl Bangladesh virus</i> (ToLCBV)	Bangladesh	ICTV (2011)
Tomato leaf curl Cameroon virus (ToLCCMV)	Cameroon	NCBI, on line - Reference Sequence: HE659516
Tomato leaf curl Cebu virus (ToLCCeV)	Philippines	Tsai et al. (2011)
<i>Tomato leaf curl China virus</i> (ToLCCNV)	China	ICTV (2011)
<i>Tomato leaf curl Comoros virus</i> (ToLCKMV)	Comoros, Mayotte	NCBI, on line - Reference Sequences: AM701759, AJ865341
Tomato leaf curl Cotabato virus (ToLCCoV)	Philippines	Tsai et al. (2011)
Tomato leaf curl Diana virus (ToLCDiV)	Madagascar	NCBI, on line - Reference Sequence: AM701765
Tomato leaf curl Ghana virus (ToLCGV)	Ghana	Osei et al. (2008)
<i>Tomato leaf curl Guangdong virus</i> (ToLCGdV)	China	ICTV (2011)
<i>Tomato leaf curl Guangxi virus</i> (ToLCGxV)	China	ICTV (2011)
<i>Tomato leaf curl Gujarat virus</i> (ToLCGuV)	India	ICTV (2011)
Tomato leaf curl Hainan virus (ToLCHnV)	China, Vietnam	NCBI, on line - Reference Sequence: HQ162269 ; Zhang et al. (2010)

Species name (acronym)	Occurrence	References
<i>Tomato leaf curl Hsinchu virus</i> (ToLCHsV)	Taiwan	ICTV (2011)
<i>Tomato leaf curl Ilocos virus</i> (ToLCiV)	Phillipines	NCBI, on line - Reference Sequence: EU295552
<i>Tomato leaf curl Java virus</i> (ToLCJaV)	Indonesia	ICTV (2011)
<i>Tomato leaf curl Joydebpur virus</i> (ToLCJoV)	India	ICTV (2011)
<i>Tomato leaf curl Karnataka virus</i> (ToLCKaV)	India	ICTV (2011)
<i>Tomato leaf curl Kerala virus</i> (ToLCKeV)	India	ICTV (2011)
<i>Tomato leaf curl Laguna virus</i> (ToLCLaV)	Phillipines	Matsuda et al. (2008)
<i>Tomato leaf curl Laos virus</i> (ToLCLV)	Laos	ICTV (2011)
<i>Tomato leaf curl Madagascar virus</i> (ToLCMGV)	Madagascar	ICTV (2011)
<i>Tomato leaf curl Malaysia virus</i> (ToLCMYV)	Malaysia	ICTV (2011)
<i>Tomato leaf curl Mali virus</i> (ToLCMLV)	Mali	ICTV (2011)
<i>Tomato leaf curl Mayotte virus</i> (ToLCYTV)	Mayotte	ICTV (2011)
<i>Tomato leaf curl Mindanao virus</i> (ToLCMiV)	Phillipines	Tsai et al. (2011)
<i>Tomato leaf curl Mohely virus</i> (ToLCMoV)	Comoros	NCBI, on line - Reference Sequence: AM701763
<i>Tomato leaf curl Namakely virus</i> (ToLCNaV)	Comoros, Madagascar	NCBI, on line - Reference Sequence: AM701761, AM701764
<i>Tomato leaf curl New Delhi virus</i> (ToLCNDV)	India, Pakistan, Thailand	ICTV (2011)
<i>Tomato leaf curl Nigeria virus</i> (ToLCNGV)	Nigeria	Kon and Gilbertson (2012)
<i>Tomato leaf curl Ouani virus</i> (ToLCOuV)	Comoros	NCBI, on line - Reference Sequence: AM701758
<i>Tomato leaf curl Palampur virus</i> (ToLCPaV)	India	Kumar et al. (2008)
<i>Tomato leaf curl Patna virus</i> (ToLCPaV)	India	Kumari et al. (2009)
<i>Tomato leaf curl Philippines virus</i> (ToLCPV)	Philippines	ICTV (2011)
<i>Tomato leaf curl Pune virus</i> (ToLCPuV)	India	ICTV (2011)
<i>Tomato leaf curl Rajasthan virus</i> (ToLCRaV)	India	NCBI, on line - Reference Sequence: DQ339117
<i>Tomato leaf curl Seychelles virus</i> (ToLCSCV)	Seychelles	ICTV (2011)
<i>Tomato leaf curl Sinaloa virus</i> (ToLCSiV)	Costa Rica, Mexico, Nicaragua, Guatemala	Rojas et al. (2005a)
<i>Tomato leaf curl Sri Lanka virus</i> (ToLCLKV)	Sri Lanka	ICTV (2011)
<i>Tomato leaf curl Sudan virus</i> (ToLCSDV)	Sudan	NCBI, on line - Reference Sequences: HE819244
<i>Tomato leaf curl Sulawesi virus</i> (ToLCSuV)	Indonesia	Tsai et al. (2009)
<i>Tomato leaf curl Taiwan virus</i> (ToLCTV)	Taiwan	ICTV (2011)
<i>Tomato leaf curl Togo virus</i> (ToLCTOV)	Togo	NCBI, on line - Reference Sequence: HE659517
<i>Tomato leaf curl Toliara virus</i> (ToLCToV)	Madagascar	NCBI, on line - Reference Sequence: AM701768
<i>Tomato leaf curl Uganda virus</i> (ToLCUV)	Uganda	Shih et al. (2006)
<i>Tomato leaf curl Vietnam virus</i> (ToLCVV)	Vietnam	ICTV (2011)
<i>Tomato leaf curl virus</i> (ToLCV)	Australia	ICTV (2011)
<i>Tomato leaf deformation virus</i> (ToLDeV)	Ecuador, Peru	Marquez-Martin et al. (2011)
<i>Tomato leaf distortion virus</i> (ToLDV)	Brazil	Castillo-Urquiza et al. (2008)
<i>Tomato mild mosaic virus</i> (ToMMV)	Brazil	Castillo-Urquiza et al. (2008)
<i>Tomato mild yellow leaf curl Aragua virus</i> (ToMYLCAV)	Venezuela	ICTV (2011)
<i>Tomato mosaic Havana virus</i> (ToMHaV)	Cuba, Honduras, Jamaica	ICTV (2011)
<i>Tomato mottle Taino virus</i> (ToMoTaV)	Cuba	Polston and Anderson (1997)
<i>Tomato mottle virus</i> (ToMoV)	Belize, Mexico, Puerto Rico, USA (Florida)	Polston and Anderson (1997)

Species name (acronym)	Occurrence	References
<i>Tomato rugose mosaic virus</i> (ToRMV)	Brazil	ICTV (2011)
<i>Tomato severe leaf curl virus</i> (ToSLCV)	Guatemala, Honduras, Nicaragua	ICTV (2011)
<i>Tomato severe rugose virus</i> (ToSRV)	Brazil	ICTV (2011)
<i>Tomato yellow leaf curl Axarquia virus</i> (TYLCAxV)	Spain	ICTV (2011)
<i>Tomato yellow leaf curl China virus</i> (TYLCCNV)	China	ICTV (2011)
<i>Tomato yellow leaf curl Chuxiong virus</i> (TYLCCHuV)	China	Li et al. (2004)
<i>Tomato yellow leaf curl Dan Xa virus</i> (TYLCDXV)	Vietnam	NCBI, on line - Reference Sequence: EU189150
<i>Tomato yellow leaf curl Guangdong virus</i> (TYLCGdV)	China	ICTV (2011)
<i>Tomato yellow leaf curl Indonesia virus</i> (TYLCIDV)	Indonesia	ICTV (2011)
<i>Tomato yellow leaf curl Iran virus</i> (TYLCIRV)	Iran	Bananej et al. (2004)
<i>Tomato yellow leaf curl Kanchanaburi virus</i> (TYLCKaV)	Vietnam, Thailand	Green et al. (2003); Ha et al. (2008)
<i>Tomato yellow leaf curl Malaga virus</i> (TYLCMaV)	Spain	ICTV (2011)
<i>Tomato yellow leaf curl Mali virus</i> (TYLCMLV)	Mali	ICTV (2011)
<i>Tomato yellow leaf curl Sardinia virus</i> (TYLCSV)	Canary Islands, Greece, Israel, Italy, Jordan, Morocco, Spain, Tunisia	Navas-Castillo et al.(2011)
<i>Tomato yellow leaf curl Thailand virus</i> (TYLCTHV)	Thailand, Myanmar	ICTV (2011)
<i>Tomato yellow leaf curl Vietnam virus</i> (TYLCVV)	Vietnam	Ha et al. (2008)
<i>Tomato yellow leaf curl virus</i> (TYLCV)	Antigua and Barbuda, Australia, Belize, Canary Islands, China, Cuba, Cyprus, Dominican Republic, Egypt, France, Greece, Grenada, Guadeloupe, Guademaal, Haiti, Hawaii, Iran, Israel, Italy, Jamaica, Japan, Jordan, Lebanon, Martinique, Mauritius, Mexico, Morocco, Netherlands, Oman, Portugal, Puerto Rico, Reunion, Saint Kitts and Nevis, Saudi Arabia, South Korea, Spain, Sudan, Syria, Bahamas, Tunisia, Turkey, USA, Venezuela	Navas-Castillo et al.(2011)
<i>Tomato yellow leaf distortion virus</i> (ToYLDV)	Cuba	Fiallo-Olive et al. (2009)
<i>Tomato yellow margin leaf curl virus</i> (TYMLCV)	Venezuela	Nava et al. (2006)
<i>Tomato yellow spot virus</i> (ToYSV)	Argentina, Brazil	NCBI, on line - Reference Sequence: FJ538207; Fernandes et al. (2006)
<i>Tomato yellow vein streak virus</i> (ToYVSV)	Argentina, Brazil	ICTV (2011)

Note: According to the ICTV, on line, Master Species list 2011 and compiled from Jones (2003), Navas-Castillo et al. (2011) and NCBI, on line. The names of the type species are in italics.

Table B.7: Whitefly-transmitted begomoviruses infecting cucurbits

Species Name (Acronym)	Occurrence	Host plants	References
<i>Cucurbit leaf crumple virus</i> (CuLCrV)	Mexico, USA	<i>Citrullus lanatus</i> , <i>Cucumis melo</i> var. <i>Cantalupensis</i> , <i>Cucurbita pepo</i>	Brown et al. (2000, 2002), Guzman et al. (2000)
<i>Melon chlorotic leaf curl virus</i> (MCLCV)	Guatemala	<i>Cucumis melo</i>	Brown et al. (2001)
Melon leaf curl virus (MLCV)	USA	<i>Cucumis melo</i>	Fauquet et al. (2003)
<i>Squash leaf curl China virus</i> (SLCCNV)	China	<i>Cucurbita</i> sp.	Fauquet et al. (2003)
<i>Squash leaf curl virus</i> (SLCV)	USA	<i>Cucurbita pepo</i> , <i>C. maxima</i> , <i>C. moschata</i> , <i>Cucumis melo</i> , <i>Phaseolus vulgaris</i>	Fauquet et al. (2003)
<i>Squash leaf curl Yunnan virus</i> (SLCCYV)	China (Yunnan)	<i>Cucurbita</i> sp.	Fauquet et al. (2003)
<i>Squash mild leaf curl virus</i> (SMLCV)	USA (California)	<i>Cucurbita</i> sp	Fauquet et al. (2003)
Squash yellow mild mottle virus (SYMMoV)	Costa Rica	<i>Carica papaya</i> , <i>Citrullus</i> sp., <i>Cucurbita pepo</i>	Fauquet et al. (2003)
Tobacco leaf curl China virus (TbLCCV) (syn. <i>Squash leaf curl China virus</i>)	China	<i>Cucurbita pepo</i> , <i>C. moschata</i> , <i>Cucumis melo</i> , <i>Nicotiana tabacum</i> , <i>Phaseolus vulgaris</i>	Fauquet et al. (2003)
Tomato leaf curl Barbados virus (ToLCBBV)	Barbados	<i>Capsicum annuum</i> , <i>Cucumis melo</i> , <i>Cucurbita maxima</i> , <i>Lycopersicon esculentum</i> , <i>Phaseolus vulgaris</i> , <i>Solanum melongena</i>	Roye et al. (2000)
<i>Watermelon chlorotic stunt virus</i> (WmCSV)	Iran, Saudi Arabia, Sudan, Yemen	<i>Citrullus lanatus</i> , <i>C. colocynthis</i>	Fauquet et al. (2003)
Watermelon curly mottle virus (WmCMV)	USA	<i>Citrullus lanatus</i> , <i>Cucumis melo</i> var. <i>Cantalupensis</i>	Fauquet et al. (2003)

Note: names in italics are ICTV recognised species; those in non-italics are species meeting the ICTV criteria but not yet approved.

Table B.8: Viruses transmitted by *B. tabaci* in a non-circulative mode of transmission

Genus	Species Name (acronym)	Occurrence	Host plants	References
Crinivirus	<i>Cucurbit yellow stunting disorder virus</i> (CYSDV)	France, Portugal, Spain, Turkey, United Arab Emirates, Saudi Arabia, Jordan, Morocco, Lebanon, USA, Mexico, China, Greece, Tunisia, Iran	<i>Cucurbitaceae</i> , <i>Phaseolus vulgaris</i>	Celix et al. (1996), Rubio et al. (1999, 2001), Desbiez et al. (2000), Kao et al. (2000), Louro et al. (2000a), Desbiez et al. (2003), Boubourakas et al. (2006), Wintermantel et al. (2007), Yakoubi et al. (2007), Liu et al. (2010b), NCBI, on line
	<i>Tomato chlorosis virus</i> (ToCV)	Spain, Portugal, Italy, Greece, Canary Islands (ES), France, Cyprus, Turkey, Brazil, Costa Rica, Cuba, Israel, Japan, Lebanon, Mauritius, Mayotte (FR), Mexico, Morocco, Puerto Rico (US), Réunion (FR), South Africa, Taiwan, USA	<i>Lycopersicon esculentum</i> , <i>Capsicum annuum</i>	Louro et al. (2000b), Navas-Castillo et al. (2000), Accotto et al. (2001), Jones (2001), Wintermantel et al. (2001), Hanafi (2002), Font et al. (2003), Segev et al. (2004), Tsai et al. (2004), Dalmon et al. (2005), Dovas et al. (2002), Abou-Jawday et al. (2006), Delatte et al. (2006), Papayiannis et al. (2006), Wintermantel and Wisler (2006), Alvarez-Ruiz et al. (2007), Barbosa et al. (2008), Cevik and Erkiß (2008), Martinez-Zubiaur et al. (2008), Masse et al. (2008), Castro et al. (2009), Lett et al. (2009), Hirota et al. (2010)
	<i>Bean yellow disorder virus</i> (BnYDV)	Spain	<i>Phaseolus vulgaris</i>	Segundo et al. (2004)
	<i>Lettuce chlorosis virus</i> (LCV)	USA	<i>Lactuca sativa</i> , <i>Beta vulgaris</i>	Duffus et al. (1996)
	<i>Lettuce infectious yellows virus</i> (LIYV)	USA	<i>Lactuca sativa</i> , <i>Beta vulgaris</i> , rucifers and cucurbits	Duffus et al. (1986)
	<i>Sweet potato chlorotic stunt virus</i> (SPCSV)	Spain, USA, China, Argentina, Peru, Korea, Ethiopia, Uganda, Kenya, Tanzania, Nigeria, Costa Rica	<i>Ipomoea batatas</i>	Winter et al. (1992), Aritua et al. (1998), Di Feo et al. (2000), Yun et al. (2002), Gutierrez et al. (2003), Ateka et al., (2004), Valverde and Moreira (2004), Valverde et al. (2004), Abad et al. (2007), Ndunguru and Kapinga (2007), Adane (2010), Qiao et al. (2011), Tewodros et al. (2011)
	<i>Cucurbit chlorotic yellows virus</i> (CCYV)	Japan, China, Taiwan, Sudan	<i>Cucurbitaceae</i>	Huang et al. (2010), Okuda et al. (2010), Gu et al. (2011), Hamed et al. (2011),
Ipomovirus	<i>Cassava brown streak virus</i> (CBSV)	Kenya, Tanzania, Malawi, Mozambique, Uganda, Rwanda, Burundi	<i>Manihot esculenta</i>	Nichols (1950), Thresh et al. (1994), Monger et al. (2001), Alicai et al. (2007), CABI on line 2007, FAO (2010),

Genus	Species Name (acronym)	Occurrence	Host plants	References
	<i>Ugandan cassava brown streak virus</i> (UCBSV)	Kenya, Tanzania, Malawi, Uganda, Burundi, Democratic Republic Congo	<i>Manihot esculenta</i>	Bigirimana et al. (2011), Mbanzibwa et al. (2011), Adams et al. (2012), Mulimbi et al. (2012)
	<i>Cucumber vein yellowing virus</i> (CVYV)	Spain, Portugal, France, Cyprus, Turkey, Israel, Jordan, Sudan, Tunisia, Iran	<i>Cucurbitaceae</i>	Cohen and Nitzany (1960), Al-Musa et al. (1985), Yilmaz et al. (1989), Cuadrado et al. (2001), Louro et al. (2004), Papayiannis et al. (2005), Lecoq et al. (2007), Yakoubi et al. (2007)
	<i>Squash vein yellowing virus</i> (SqVYV)	USA	<i>Cucurbitaceae</i>	Adkins et al. (2007)
	<i>Sweet potato mild mottle virus</i> (SPMMV)	Burundi, Kenya, Rwanda, Tanzania, Uganda, Indonesia, Philippines, Egypt, New Zealand, South Africa	<i>Ipomoea batatas</i>	Mukasa et al. (2003), Tugume et al. (2010)
	<i>Tomato mild mottle virus</i> (ToMMV)	Israel, Jordan, Ethiopia, Yemen	<i>Lycopersicon esculentum</i> , <i>Solanum melongena</i>	Walkey et al. (1994), Hiskias et al. (1999), Abraham et al. (2012), Dombrovsky et al. (2012)
Carlavirus	<i>Cowpea mild mottle virus</i> (CpMMV)	Egypt, Israel, India, Indonesia, Malaysia, Thailand, Yemen, Côte d'Ivoire, Egypt, Ghana, Kenya, Malawi, Mozambique, Nigeria, Sudan, Tanzania, Togo, Uganda, Zambia, Brazil, Fiji, Papua New Guinea, Solomon Islands, Iran	<i>Phaseolus vulgaris</i> , <i>Lycopersicon esculentum</i>	Thouvenel et al. (1982), Tavasoli et al. (2009), CABI/EPPO, on line
	<i>Melon yellowing-associated virus</i> (MYaV)	Brazil	<i>Cucumis melo</i>	Nagata et al. (2003)
Torrado-virus	<i>Tomato torrado virus</i> (ToTV)	Canary Islands, Spain, Hungary, Poland, Italy, France, Panama, Australia, Colombia	<i>Lycopersicon esculentum</i> , <i>Capsicum annum</i>	Alfaro-Fernández et al. (2007), Verbeek et al. (2007), Alfaro-Fernández et al. (2009), Herrera-Vásquez et al. (2009), Gambley et al. (2010), Verbeek and Dulleman (2012), EPPO, 2013

Note: names in italics are ICTV recognised species; those in non-italics are species meeting the ICTV criteria but not yet approved.

3. Biological characteristics of European and non-European populations of *B. tabaci*

Table B.9: Biological characteristics of European and non-European populations of *B. tabaci* tested on crop and weed host plants

Biological parameters	<i>B. tabaci</i> species (geographical origin)	Host plants	Range of temperatures (°C)					References
			15–17	19–21	25–26	28–30	31–35	
Mean development time (days), egg to adult stage	MEAM1 (Turkey)	Cucumber Cantaloupe Squash Watermelon		33.5 36.5 37.2 38.9	19.3 20.8 20.1 23.8	16.8 19.6 19.8 21.9		Bayhan et al. 2006a
	MEAM1 (Japan)	Cabbage Cucumber Tomato Egg-plant Bell pepper Kidney beans			23.2 22.6 23.7 21.3 22.5 0-26.5			Iida et al. 2009
	Med (Japan)	Cabbage Cucumber Tomato Egg-plant Bell pepper Kidney beans			28.8 24.6 28 28.4 35.2 24.1-28			Iida et al. 2009
	MEAM1 (Japan)	Tomato Cucumber		39.8 38.7	21.6 19.8	18.1 15.8	23 26.7	Tsueda and Tsuchida 2011
	Med (Japan)	Tomato Cucumber		42.9 37.1	21.9 19.8	19.2 16	- 25.5	Tsueda and Tsuchida 2011
	MEAM1 (China)	Bean Soybean Cowpea			27.8 18.2 22.7			Musa and Ren 2005
	MEAM1 (China)	Cotton Tobacco Cabbage Squash Kidney bean				23.5 22.5 23.6 21.4 19.2		Zang et al. 2006
	Asia II (China)	Cotton Tobacco Cabbage Squash Kidney bean				21.5 - - 22.9 -		Zang et al. 2006
	MEAM1 (USA - Georgia)	Cotton <i>Deltapine 50</i> Cotton <i>Stoneville 453</i>		37.8 37.9	21.3 21.5	16.3 18.3	23.1 18.9	Nava-Camberos et al. 2001

		Cantaloupe <i>Tam Sun</i> Cantaloupe <i>Gold Rush</i>		36.0 35.9	20.7 21.4	14.8 14.6	19.5 19.4	
	MEAM1 (south of Spain)	Sweet pepper	45.3	36.6	21.5	18	16.8-19.8	Muñiz and Nombela 2001
	Med (south of Spain)	Sweet pepper	42.7	34.1	20.7	16.2	16-18.1	Muñiz and Nombela 2001
	MEAM1 (Spain)	<i>Solanum nigrum</i> <i>Datura stramonium</i>			21.8 23.4			Muñiz 2000a
	Med (Spain)	<i>Solanum nigrum</i> <i>Datura stramonium</i>			20.2 21.9			Muñiz 2000a
	Med (south of France)	Tomato	55.8	39.6	25.6	20.2	20.5	Bonato et al. 2007
	Italy (Italy)	<i>Euphorbia characias</i>	77.5	48.1	35.4	29.7	35.7	Demichelis et al. 2005
Survival (%), egg to adult stage								
	MEAM1 (Turkey)	Cucumber Cantaloupe Squash Watermelon		73.2 72.9 52.1 37.6	83.2 84.9 76.1 64.8	72.9 75.6 57.1 40.1		Bayhan et al. 2006a
	MEAM1 (Japan)	Cabbage Cucumber Tomato Egg-plant Bell pepper Kidney beans			76.4 77.9 94.3 93.2 6.1 0-41.3			Iida et al. 2009
	Med (Japan)	Cabbage Cucumber Tomato Egg-plant Bell pepper Kidney beans			62.1 90.6 64.9 96.3 73 71-83.9			Iida et al. 2009
	MEAM1 (China)	Bean Soybean Cowpea			77.1 64.3 70.1			Musa and Ren 2005
	MEAM1 (China)	Cotton Tobacco Cabbage Squash Kidney bean				86.2 55.2 79 62 64.6		Zang et al. 2006
	Asia II (China)	Cotton Tobacco Cabbage Squash Kidney bean				77.8 0 0 26 0		Zang et al. 2006
	MEAM1 (USA - Georgia)	Cotton <i>Deltapine 50</i> Cotton <i>Stoneville 453</i>		37.3 64.4	41.3 39.0	55.9 38.2	42.5 56.7	Nava-Camberos et al. 2001

		Cantaloupe <i>Tam Sun</i> Cantaloupe <i>Gold Rush</i> Pepper <i>Jalapa</i> Pepper <i>Jupiter</i>		100 78.1 0 0	91.3 85.9 0 8.3	98.1 76.5 0 0	84.0 88.5 0 0	
	Med (south of France)	Tomato	48	83	85	82	63	Bonato et al. 2007
	MEAM1 (Spain)	<i>Malva parviflora</i> <i>Capsella bursa-pastoris</i> <i>Brassica kaber</i> <i>Lactuca serriola</i>			75.7 63.6 34.8 26.5			Muñiz 2000a
	Med (Spain)	<i>Malva parviflora</i> <i>C. bursa-pastoris</i> <i>Brassica kaber</i> <i>Lactuca serriola</i>			86.9 57 45.3 28.9			Muñiz 2000a
Adult longevity (days)	Med (south of France)	Tomato	39.6	27.3	21.9	14.6	8.5	Bonato et al. 2007
	MEAM1 females (China)	Bean Soybean Cowpea			9.8 12.3 11.7			Musa and Ren 2005
	MEAM1 (China)	Cotton Tobacco Cabbage Squash Kidney bean				20.3 2.2 14.6 6.1 6		Zang et al. 2006
	Asia II (China)	Cotton Tobacco Cabbage Squash Kidney bean				11.2 1.7 1.2 2.2 2.1		Zang et al. 2006
	MEAM1 (Japan)	Tomato Cucumber		24.1 26.7		11.4 11.9		Tsueda and Tsuchida 2011
	Med (Japan)	Tomato Cucumber		21.4 23.7		11.4 11.6		Tsueda and Tsuchida 2011
Fecundity (total number of eggs per female)	Med (south of France)	Tomato	49.5	105.3	94.2	58.6	41	Bonato et al. 2007
	MEAM1 females (China)	Bean Soybean Cowpea			98 160.9 153.1			Musa and Ren 2005
	MEAM1 (Japan)	Tomato Cucumber		105.8 162.1		127.9 135.8		Tsueda and Tsuchida 2011
	Med (Japan)	Tomato Cucumber		67.9 149.3		68 81.8		Tsueda and Tsuchida 2011

C. DISTRIBUTION OF *BEMISIA TABACI*, TRADE VOLUME

Table C.1: Distribution and first report of *B. tabaci* in the EU-27

Country	Distribution	First reported	Sources and references	
				Comments *
Austria	Restricted distribution	1989	(1) (3)	
Belgium	Restricted distribution		(1)	
Bulgaria	Present, few occurrences		(1)	
Cyprus	Widespread		(1) (3)	Brown et al. (1995b): identification of MEAM1 specimens Vassiliou et al. (2008): only the MEAM1 species reported
Czech Republic	Restricted distribution	1988	(1)	
Denmark	Eradicated	1988	(1)	
Estonia	Absent, confirmed by survey		(1)	
Finland	Present, very few occurrences Present, under eradication		(1)	EPPO 2012c: outbreak of <i>B. tabaci</i> in April 2012 in two glasshouses
France	Present, few occurrences	1988	Della Giustina et al. (1989); (1) (2)	EPPO 1997a: all samples collected in Provence-Alpes-Côte-d'Azur were identified as MEAM1 <i>B. tabaci</i> Guirao et al. (1997b): report of the MEAM1 species EPPO 2002; Reynaud (2000): with one exception all populations found in a 1997/1999 survey were from the MEAM1 species. Dalmon et al. (2008): with one exception (ie. botanical garden glasshouse in Nice), all the populations sampled were from the Med species, northern limit of <i>B. tabaci</i> : north of Aquitaine, Pyrénées Orientales and Provence-Alpes-Côtes-d'Azur. Gauthier (2010): all samples were identified as species Med, few specimens of the SSA2 species reported in the south of France
Corsica	Present, no further details		(1)	
Germany	Restricted distribution	1987	(1)	
Greece	Widespread	1889	(1)	First description of <i>B. tabaci</i>

Country	Distribution	First reported	Sources and references	
				Comments *
				(<i>Aleyrodes tabaci</i>) by Gennadius (1889)
Rhodes islands	Present, no further details			EPPO 2009b, Papayiannis et al. (2008): the MEAM1 species present on Rhodes islands
Crete	Present, no further details			Tsagkarakou et al. (2007, 2012): only the Med species
Hungary	Present, few occurrences	1990	(1)	
Ireland	Eradicated	1997	(1)	
Italy	Widespread		(1) (2) (3)	EPPO, 2000a: found on various hot plants in Central Italy
Sardinia	Widespread		(1)	Simón et al. (2003), Demichelis et al. (2005): first report of the Italy species
Sicily	Present, no further details		(1) (3)	(3) both MEAM1 and Med species found in Sicily (2008)
Southern Italy	Present			Parrella et al. (2012) Med predominates over MEAM1, and report of a new genetic variant in southern Italy
Latvia	Absent or extinct, confirmed by survey		(1)	
Lithuania	Absent, intercepted only		(1)	
Luxembourg	No data			
Malta	Restricted distribution, no further details	1993	(1)	
Netherlands	Widespread	1987	(1) (3)	Fransen (1994): the MEAM1 species identified
Poland	Restricted distribution	1988	(1)	
Portugal	Restricted distribution	1995	(1) (3) Lopes (2002)	EPPO, 1997b: the MEAM1 species was only found in the South (Algarve region) Lopes (2002): presence of <i>B. tabaci</i> also in Alentejo and Ribatejo e Oeste regions
Romania	Established	1969	(2)	
Slovakia	Absent, never occurred		(1)	
Slovenia	Eradicated	1998	(1)	
Spain	Present Present, no further details	1943	Pascual & Callejas (2004) citing Gomez-Menor (1943); (1) (3)	Guirao et al. (1997a): presence of MEAM1- and non- MEAM1 species EPPO, 2000b: presence confirmed in the Canary Islands

Country	Distribution	First reported	Sources and references	
			Comments *	
				Arno et al. (2009); BemisiaRisk (2010): Med- predominant over MEAM1 species Banks et al. (1995) in De la Rúa et al. (2006): first report of the SSA2-species
Sweden	Present, few occurrences Under eradication	1987	(1) Nilsson (2006)	
United Kingdom England and Wales	Eradicated, intercepted Eradicated	1987	(1) (3) Cuthbertson et al. (2011)	“Since 1987, <i>B. tabaci</i> has been intercepted at growing sites on an extremely wide range of hosts at nurseries” Cuthbertson et al. (2011) Powell et al. (2012) First record of the Med species

(1) CABI, on line

(2) DAISIE, on line

(3) EPPO PQR, 2012b

Note: The terms MEAM1, Med, Italy and sub-Saharan Africa 2 species (SSA2) used in the comments refer to B, Q, T, and S biotypes, respectively, as sometimes cited in the references.

Table C.2: *B. tabaci* distribution in open fields in the risk assessment area including information from Bosnia and Herzegovina, Croatia and Turkey

Site Nr.	GPS coordinates		Country	Record source	Species	Locality
	Latitude	Longitude				
1	43.015	17.81333333	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
2	43.02027778	17.7625	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
3	43.04555556	17.67777778	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
4	43.06361111	17.69472222	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
5	43.06722222	17.71166667	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
6	43.09222222	17.72861111	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
7	43.09555556	17.71166667	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
8	43.19694444	17.54222222	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
9	43.22194444	17.54222222	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
10	43.26555556	17.40666667	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
11	43.39972222	17.33888889	Bosnia and Herzegovina	Ostojic et al. (2010)	NSI	
12	28.00599444	-14.59333333	Canary Islands	De Barro (2012 pers. comm)	MEAM1	
13	28.48333333	-15.67805556	Canary Islands	Moya et al. (2001)	MEAM1	
14	42.55235	18.305	Croatia	De Barro (2012, pers. comm.)	Med	
15	43.04305556	16.08472222	Croatia	Žanić et al. (2003)	Med	
16	43.06194444	16.16944444	Croatia	Žanić et al. (2003)	Med	
17	43.44472222	16.69472222	Croatia	Žanić et al. (2001)	NSI	
18	43.50590833	16.49138889	Croatia	De Barro (2012, pers. comm.)	Med	
19	43.5125	16.25416667	Croatia	Žanić et al. (2001)	NSI	
20	43.51388889	16.4575	Croatia	Žanić et al. (2001, 2003)	Med	
21	34.71666667	32.52527778	Cyprus	Vassiliou et al. (2008)	MEAM1	Mandria
22	34.74583333	33.1525	Cyprus	Vassiliou et al. (2008)	MEAM1	Pareklisia
23	34.76666667	33.35583333	Cyprus	Vassiliou et al. (2008)	MEAM1	Maroni
24	34.80416667	32.40666667	Cyprus	Tsagkarakou et al. (2007); Vassiliou et al. (2008)	MEAM1/Med	Chloraka
25	34.80833333	33.42361111	Cyprus	Vassiliou et al. (2008)	MEAM1	Alaminos
26	34.80833333	32.42361111	Cyprus	Vassiliou et al. (2008)	MEAM1	Lemba
27	34.85	33.57611111	Cyprus	Vassiliou et al. (2008)	MEAM1	Kiti
28	34.925	33.42361111	Cyprus	Tsagkarakou et al. (2007)	MEAM1	Pirgos
29	35.02083333	33.16944444	Cyprus	Vassiliou et al. (2008)	MEAM1	Klirou

Site Nr.	GPS coordinates		Country	Record source	Species	Locality
	Latitude	Longitude				
30	35.03666667	32.42361111	Cyprus	Vassiliou et al. (2008)	MEAM1	Polis
31	35.0375	33.98277778	Cyprus	Vassiliou et al. (2008)	MEAM1	Paralimni
32	35.075	33.11861111	Cyprus	Vassiliou et al. (2008)	MEAM1	Ayia Marina
33	35.13333333	33.11861111	Cyprus	Vassiliou et al. (2008)	MEAM1	Akaki
34	35.14166667	33.03388889	Cyprus	Vassiliou et al. (2008)	MEAM1	Astromeritis
35	35.21972222	32.99972222	Cyprus	De Barro (2012, pers. comm.)	Med	Morphou (Guzelyourt)
36	42.66666667	2.83027778	France	Gauthier (2010)	Med	Toulouges
37	42.71194444	2.84722222	France	Gauthier (2010)	Med	St Estève
38	43.11944444	6.13555556	France	Gauthier (2010)	Med	Hyères
39	43.15	6.06777778	France	Guirao et al. (1997b)	MEAM1	La Crau
40	43.28333333	5.57611111	France	Gauthier (2010)	Med	Aubagne
41	43.44583333	5.10166667	France	Villeveille and Lecoq (1992)	NSI	Etang De Berre
42	43.56666667	3.89805556	France	Gauthier (2010)	SSA2	Lattes
43	43.58333333	7.11861111	France	Guirao et al. (1997b), Delatte et al. (2005)	MEAM1	Antibes
44	43.7	7.25416667	France	Guirao et al. (1997b)	MEAM1	Nice
45	43.8375	5.03388889	France	Villeveille et Lecoq (1992)	NSI	Cavaillon (Vaucluse)
46	44.93333333	4.89805556	France	Ramel (2013, pers. comm.)	NSI	Valence
47	43.83777778	4.35583333	France	Ramel (2013, pers. comm.)	NSI	Nîmes
48	44.12805556	4.06777778	France	Ramel (2013, pers. comm.)	NSI	Alès
49	43.29638889	5.37277778	France	Gauthier et al. (2011),	NSI	Marseille
50	43.67666667	4.62694444	France	Gauthier et al. (2011),	NSI	Arles
51	43.60444444	1.44055556	France	Gauthier et al. (2011),	NSI	Toulouse
52	42.69861111	2.89805556	France	Gauthier et al. (2011),	NSI	Perpignan
53	43.69583333	7.27111111	France	Dalmon et al. (2008)	NSI	Nice
54	43.66666667	6.93194444	France	Dalmon et al. (2008)	NSI	Grasse
55	34.9575	24.86416667	Greece	Saleh (2008)	Med	Antiskari
56	35.01	25.74555556	Greece	Tsagkarakou et al. (2012)	Med	Ierapetra
57	35.06666667	24.72861111	Greece	Tsagkarakou et al. (2012)	Med	Tympaki
58	35.08722222	24.74555556	Greece	Saleh (2008)	Med	Agias Galinis (Timbaki region)
59	35.2	26.08472222	Greece	Tsagkarakou et al. (2012)	Med	Siteia
60	35.325	25.11861111	Greece	De Barro (2012, pers. comm.)	Med	Heraklion
61	35.33138889	25.32194444	Greece	De Barro (2012, pers. comm.)	Med	Gavdou
62	35.36472222	24.47444444	Greece	Tsagkarakou et al. (2012)	Med	Rethymno
63	35.475	23.96583333	Greece	De Barro (2012, pers. comm.)	Med	Marmarás
64	35.51222222	24	Greece	Tsagkarakou et al. (2012)	Med	Chania
65	35.51666667	24.13555556	Greece	Tsagkarakou et al. (2007)	Med	Sternai
66	36.28333333	27.88111111	Greece	Papayiannis et al. (2008)	MEAM1	Mandriko
67	36.35	28	Greece	Papayiannis et al. (2008)	Med	Kameiros

Site Nr.	GPS coordinates		Country	Record source	Species	Locality
	Latitude	Longitude				
68	36.4	28.06777778	Greece	Papayiannis et al. (2008)	MEAM1	Paradisi
69	36.73333333	22.88111111	Greece	Tsagkarakou et al. (2007, 2012)	Med	Asopos
70	36.86555556	29.52527778	Greece	Saleh (2008)	Med	Schoinoussa
71	37.23666667	21.67777778	Greece	De Barro (2012, pers. comm.)	Med	Kyparissia
72	37.61666667	22.72861111	Greece	Tsagkarakou et al. (2012)	Med	Argos
73	37.63861111	22.7625	Greece	De Barro (2012, pers. comm.)	Med	Argos
74	37.8	21.35583333	Greece	Tsagkarakou et al. (2012)	Med	Amaliada
75	37.83333333	21.32194444	Greece	Tsagkarakou et al. (2007)	Med	Ampelokampos
76	38.36916667	21.42361111	Greece	Tsagkarakou et al. (2012)	Med	Mesolónghi
77	38.43333333	21.35583333	Greece	Tsagkarakou et al. (2007)	Med	Aitolikón
78	38.60972222	21.38972222	Greece	De Barro (2012, pers. comm.)	Med	Agrinion
79	38.62138889	21.40666667	Greece	Tsagkarakou et al. (2007)	Med	Agrinion
80	39.37972222	21.96583333	Greece	De Barro (2012, pers. comm.)	Med	Pródromos
81	39.39194444	21.93194444	Greece	Tsagkarakou et al. (2007)	Med	Karditsa
82	40.60416667	22.77944444	Greece	De Barro (2012, pers. comm.)	Med	Chalastra (Pirgos)
83	40.64027778	22.94888889	Greece	Tsagkarakou et al. (2007)	Med	Thessaloniki
84	41.06666667	26.27111111	Greece	Papayiannis et al. (2008)	MEAM1	Lyra
85	36.71666667	15.06777778	Italy	Cavaliere and Rapisarda (2008)	MEAM1	Pachino
86	36.78333333	14.69472222	Italy	Cavaliere and Rapisarda (2008)	MEAM1	Scicli
87	36.83333333	14.52527778	Italy	Cavaliere and Rapisarda (2008)	SSA2	Santa Croce Camerina
88	36.84305556	14.79638889	Italy	De Barro (2012, pers. comm.)	MEAM1	Contrada Torre Radosta
89	37.03333333	14.47444444	Italy	Cavaliere and Rapisarda (2008)	MEAM1/Med	Acate
90	37.33333333	13.42361111	Italy	De la Rua et al. (2006)	Italy	Siculiana
91	37.51666667	13.05083333	Italy	Cavaliere and Rapisarda (2008)	Med	Sciaccia
92	37.96666667	15.13555556	Italy	Demichelis et al, (2005)	Italy	Sella dei Mandrazzi
93	37.98333333	12.55916667	Italy	Cavaliere and Rapisarda (2008)	MEAM1/Med	Paceco
94	38.11666667	13.37277778	Italy	Cavaliere and Rapisarda (2008)	MEAM1	Palermo
95	38.2675	15.57611111	Italy	De Barro (2012, pers. comm.)	Med	Faro Superiore
96	40.06666667	15.7625	Italy	Parella et al. (2012)	NSI	Rivello
97	40.76666667	14.47444444	Italy	Parella et al. (2012)	NSI/Med	Boscotrecase
98	40.78472222	8.338888889	Italy	De Barro (2012, pers. comm.)	Med	Porto Torres
99	40.88333333	14.57611111	Italy	Parella et al. (2012)	NSI	Domicella

Site Nr.	GPS coordinates		Country	Record source	Species	Locality
	Latitude	Longitude				
100	40.9	14.50833333	Italy	Parella et al. (2012)	NSI	Saviano
101	41.01666667	14.915	Italy	Parella et al. (2012)	NSI/Med	Torre le Nocelle
102	41.06666667	14.32194444	Italy	Parella et al. (2012)	Med	Caserta
103	41.13333333	16.86416667	Italy	De le Rua et al. (2006)	Italy	Bari
104	41.44222222	13.03388889	Italy	De Barro (2012, pers. comm.)	Med	Pontinia
105	44.0975	8.203333333	Italy	De Barro (2012, pers. comm.)	Med	Ceriale
106	44.14333333	12.23722222	Italy	Guirao et al.(1997b)	MEAM1	Cesena
107	37.01694444	-6.068055556	Portugal	Lopes (2002)	NSI	Faro
108	37.02427778	-6.152777778	Portugal	Lopes (2002)	NSI	Olhão
109	37.05	-6.017222222	Portugal	Moya et al. (2001)	MEAM1/Med	Patacao
110	37.08835833	-6.017222222	Portugal	Lopes (2002)	NSI	Loulé
111	37.12581111	-6.356111111	Portugal	Lopes (2002)	NSI	Tavira
112	37.14715278	-7.525555556	Portugal	Lopes (2002)	NSI	Lagoa
113	37.89972222	-7.813611111	Portugal	Lopes (2002)	NSI	Aljustrel
114	37.94135833	-6.356111111	Portugal	Lopes (2002)	NSI	Serpa
115	38.01395556	-7.305277778	Portugal	Lopes (2002)	NSI	Santiago do Cacém
116	38.03277778	-7.203611111	Portugal	De Barro (2012, pers. comm.)	NSI	Santo Andre
117	38.05828889	-7.898333333	Portugal	Lopes (2002)	NSI	Ferreira do Alentejo
118	38.13761389	-6.5425	Portugal	Lopes (2002)	NSI	Moura
119	38.1786	-7.440833333	Portugal	Lopes (2002)	NSI	Grândola
120	38.40047222	-7.491666667	Portugal	Lopes (2002)	NSI	Alcácer do Sal
121	38.51722222	-7.085	Portugal	Lopes (2002)	NSI	Setúbal
122	38.58416667	-7.101944444	Portugal	Lopes (2002)	NSI	Palmela
123	38.64495833	-7.796666667	Portugal	Lopes (2002)	NSI	Montemor-o-Novo
124	38.67844167	-7.5425	Portugal	Lopes (2002)	NSI	Vendas Novas
125	38.70666667	-7.017222222	Portugal	Lopes (2002)	NSI	Montijo
126	38.73333333	-6.017222222	Portugal	Lopes (2002)	NSI	Arraiolos
127	38.83029167	-8.830555556	Portugal	Lopes (2002)	NSI	Loures
128	38.86994444	-6.8475	Portugal	Lopes (2002)	NSI	Elvas
129	38.92111111	-8.983055556	Portugal	Lopes (2002)	NSI	Vila Franca de Xira
130	38.92166667	-7.915277778	Portugal	Lopes (2002)	NSI	Mora
131	38.95944444	-7.474722222	Portugal	Lopes (2002)	NSI	Coruche
132	38.96666667	-6.271388889	Portugal	Lopes (2002)	NSI	Sousel
133	39.04472222	-7.305277778	Portugal	Lopes (2002)	NSI	Salvaterra de Magos
134	39.05388889	-6.356111111	Portugal	Lopes (2002)	NSI	Fronteira
135	39.06444444	-6.101944444	Portugal	Lopes (2002)	NSI	Aviz
136	39.06944444	-7.118888889	Portugal	Lopes (2002)	NSI	Azambuja
137	39.08124444	-7.2375	Portugal	Lopes (2002)	NSI	Cartaxo
138	39.10222222	-8.745833333	Portugal	Lopes (2002)	NSI	Torres Vedras
139	39.20888889	-7.373055556	Portugal	Lopes (2002)	NSI	Almeirim

Site Nr.	GPS coordinates		Country	Record source	Species	Locality
	Latitude	Longitude				
140	39.23333333	-8.678055556	Portugal	Lopes (2002)	NSI	Lourinhã
141	39.23861111	-7.440833333	Portugal	Lopes (2002)	NSI	Alpiarça
142	39.2669	-8.8475	Portugal	Lopes (2002)	NSI	Bombarral
143	39.32111111	-7.288333333	Portugal	Lopes (2002)	NSI	Santarém
144	39.34277778	-7.051111111	Portugal	Lopes (2002)	NSI	Rio Maior
145	40.46666667	-6.762777778	Portugal	Lopes (2002)	NSI	Benavente
146	36.735	-3.8475	Spain	De Barro (2012, pers. comm.)	Med	Almayate Alto
147	36.77611111	-2.186666667	Spain	Gauthier et al. (2011)	Med	el Ejido
148	36.83333333	-2.5425	Spain	De la Rua et al. (2006)	SSA2	Almeria
149	36.85636667	-1.593333333	Spain	De Barro (2012, pers. comm.)	MEAM1	Almeria
150	36.85733889	-1.593333333	Spain	De Barro (2012, pers. comm.)	Med	Almeria
151	36.96666667	-1.796666667	Spain	Moya et al. (2001)	MEAM1/Med	Nijar
152	37.18333333	-2.39	Spain	De la Rua et al. (2006)	SSA2	Granada
153	37.37722222	-4.000277778	Spain	Moya et al. (2001)	Med	Seville
154	37.6	-1.017222222	Spain	Moya et al. (2001)	Med	Cartagena
155	37.90938611	-0.695	Spain	De Barro (2012, pers. comm.)	Med	Librilla
156	39.43260833	-0.356111111	Spain	De Barro (2012, pers. comm.)	Med	Godolleta
157	39.56666667	2.643888889	Spain	Moya et al. (2001)	Med	Palma de Mallorca
158	41.53333333	2.372777778	Spain	Gauthier et al. (2011)	NSI	Cabrils
159	41.63333333	2.728611111	Spain	Gauthier et al. (2011)	NSI	Santa Susanna
160	36.73005833	34.49138889	Turkey	De Barro (2012, pers. comm.)	Med	Mersin
161	36.8825	31.10166667	Turkey	De Barro (2012, pers. comm.)	Med	Serik
162	36.88430556	30.83027778	Turkey	De Barro (2012, pers. comm.)	Med	Ermenek
163	36.9125	30.69472222	Turkey	Erdogan et al. (2008)	MEAM1	Antalia
164	36.91777778	34.89805556	Turkey	Bayhan et al. (2006b)	MEAM1	Tarsus (Yesiltepe)
165	36.91777778	34.89805556	Turkey	Erdogan et al. (2008)	MEAM1	Tarsus
166	37	35.32194444	Turkey	De la Rua et al. (2006)	MEAM1/Med	Adana
167	37.25	40.62694444	Turkey	De Barro (2005)	Med	Cukurova
168	38.41027778	27.13555556	Turkey	Erdogan et al. (2008)	MEAM1	Izmir
169	39.93333333	32.88111111	Turkey	De Barro (2005)	Med	Ankara

Notes:

NSI, no specific identification reported.

For the sites Nos 46 to 52, the GPS coordinates and the locality cited correspond to mean data and location.

Table C.3: Records for *B. tabaci* in the EU according to EPPO, PQR, 2012b and EFSA questionnaire on *B. tabaci* and viruses it transmits sent to NPPOs in 2012 (see Appendix D)

Country	Pest status EPPO PQR	EFSA questionnaire on <i>B. tabaci</i> and viruses it transmits sent to NPPOs in 2012
Austria	Present, restricted distribution	Present, restricted distribution, in glasshouse production only, on multiple hosts
Belgium	Present, restricted distribution	Present, restricted distribution, in protected conditions, on multiple hosts mainly ornamentals
Bulgaria	Present, few occurrences	Transient, under eradication, in protected conditions, on <i>Euphorbia pulcherrima</i> (poinsettia), Hibiscus
Czech Republic	Present, restricted distribution	<u>In crop or forest production</u> : present, restricted distribution, in protected conditions, on multiple hosts <u>In nurseries</u> : present, few occurrences, in protected conditions, on multiple hosts
Cyprus	Present, widespread	No response received
Denmark	Absent, pest eradicated	<u>In crop or forest production</u> : absent, no pest record <u>In nurseries</u> : present, few occurrences, in protected conditions, on multiple hosts
Estonia	Absent, confirmed by survey	Absent, pest eradicated
Finland	Transient, under eradication	<u>In crop or forest production</u> : transient, under eradication, in protected conditions, on multiple hosts <u>In nurseries</u> : absent, pest eradicated
France	Present, restricted distribution	No response received
Germany	Present, restricted distribution	Present, no details, in protected conditions and open air, on multiple hosts
Greece	Present, widespread	<u>In crop or forest production</u> : present, widespread, in protected conditions and open air, on multiple hosts <u>In nurseries</u> : present, no details, in protected conditions and open field, on multiple hosts
Hungary	Present, few occurrences	Present, restricted distribution, in protected conditions, on tomato
Ireland	Absent, pest eradicated	Absent
Italy	Present, widespread	Present, widespread, in protected conditions and open air, on multiple hosts
Latvia	Absent, confirmed by survey	Absent, confirmed by survey
Lithuania	Absent, pest eradicated	Absent, pest eradicated
Luxembourg	No record	No response received
Malta	Present, restricted distribution	Present, widespread, in protected conditions and open air, on multiple hosts
Netherlands	Present, widespread	No response received
Poland	Present, restricted distribution	No response received
Portugal	Present, restricted distribution	No response received
Romania	No record	Absent, confirmed by survey
Slovak Republic	Absent, confirmed by survey	Absent, pest eradicated
Slovenia	Absent, pest eradicated	No response received
Spain	Present, widespread	No response received
Sweden	Present, few occurrences	Absent, pest eradicated
United Kingdom	Present, few occurrences	<u>In crop or forest production</u> : absent, confirmed by survey <u>In nurseries</u> : transient, under eradication, in protected conditions, on multiple hosts <u>Other (private gardens, urban sites, uncultivated plants, storehouses, points of sale, border stations, transport)</u> : Present, few occurrences (<i>B. tabaci</i> is occasionally found in retail outlets and infested plants are destroyed.)

Table C.4: Import volumes of “Plants for planting” into EU – summarised data for different macro-areas of origin and imported by different EU countries (in metric tonnes).

Imported in	Import from countries from region of								
	Asia	Australia	North Africa	North America	Near East	European non-EU members	Oceania	South America	South Africa
Austria	0.93			0.67	0.63	312	0.40	0.30	0.43
Belgium	196	0.17	89	351	206	99	0.03	872.27	427.70
Bulgaria	19				1.03	655			0.73
Cyprus	355	0.03	10	23	1 652	0.07			0.17
Czech Republic	60			2.2	15	1.23	0.27	5.47	0.40
Denmark	525			49	0.07	19		214.67	0.50
Estonia									
Finland	0.40			1.7	2.8	0.90		0.03	0.50
France	456	72	593	376	60	125	9.8	36.17	64.73
Germany	1 721	15	288	183	275	762	8.9	247.00	754.07
Greece	35.57			0.67	9	161			0.60
Hungary	6.53			397	11	277	0.33	1.07	1.43
Ireland	4.27	44		19	79	1.27	8.9	4.33	0.20
Italy	3 276	91	474	800	574	552	6.8	648.53	192.47
Latvia	0.20			20	0.1	1.70			0.03
Lithuania	48				1.3				0.03
Luxembourg	0.03								19.40
Malta	0.07				0.07			0.17	
Netherlands	22 342	155	404	14 796	492	1 442	10	24 371.10	5 363.47
Poland	69			3.8	19	54	0.37	7.07	2.37
Portugal	36	0.07	32	53	1.0		0.03	123.30	4.17
Romania	8.13		0.07		0.50	504			
Slovakia	1.43				0.07				0.17
Slovenia	4.53				199	231	0.27		0.07
Spain	939	27	1 782	1 018	9.5	17	1.07	1 932.80	33.73
Sweden	20			14	0.33	131		0.87	0.67
UK	499	408		112	49	21	45	9.90	64.53
EU27	30 622	812	3 672	18 222	3 657	5 370	93	28 475	6 933

*after EUROSTAT (mean for the period 2008-2010)

Table C.5: Import volumes of “Cut flowers” into EU – summarized data for different macro-areas of origin and imported by different EU countries (in metric tonnes).

Imported in	Import from countries from region of								
	Asia	Australia	North Africa	North America	Near East	European non-EU members	Oceania	South America	South Africa
Austria	4.2	0.3	0.2	5.3	0.3	695			3.8
Belgium	3.2		0.4	9 104	1 136			3 765	94
Bulgaria	0.1				34	1.4		0.2	
Cyprus	0.1		1.0		16			0.1	0.3
Czech Republic	1.7			2.2	19	3.7		3.3	
Denmark	0.03					674			0.8
Estonia									
Finland									
France	25	0.4	3.4	2.8	108	0.9		73	11
Germany	44	21	0.2	5 382	803	158		1356	109
Greece	8.4				0.2				
Hungary	10		0.03	1.0	10.1	8.3		0.5	
Ireland	0.1					2.4			
Italy	30		163	125	92	360		133.1	29.4
Latvia					0.1				
Lithuania					0.2				
Luxembourg									
Malta									
Netherlands	1 010	228	1 213	23 766	5 266	36.4	0.7	13 523	991
Poland	32				27			157	0.1
Portugal				0.03				13	2.6
Romania	1.3			0.2	3.0	4.3		1.4	
Slovakia				6.7					
Slovenia	0.1				27	14.8			
Spain	9.6		3.1	30	3.2			29	
Sweden	0.3			10	0.8	4.7		0.6	4.7
UK	297	5	3.7	98	672	3.1		386	312
EU27	1 476	255	1 388	38 533	8 217	1 967	0.7	19 440	1 558

*after EUROSTAT (mean for the period 2008-2010)

Table C.6: Import volumes of “Fruit and Vegetables” into EU – summarized data for different macro-areas of origin and imported by different EU countries (in metric tonnes).

Imported in	Import from countries from region of								
	Asia	Australia	North Africa	North America	Near East	European non-EU members	Oceania	South America	South Africa
Austria	4 725	198	2 382	2 770	3 118	223 589	292	2 874	697
Belgium	80 914	11 427	33 924	150 471	74 797	45 147	142 559	1 408 022	241 371
Bulgaria	16 487	6	4 511	4 469	7 130	167 485		17 902	2 595
Cyprus	2 939	1.4	1 383	2 231	4 057	598	70	3 186	318
Czech Republic	9 029	0.6	1 177	9 165	1 802	45 274		2 452	1 815
Denmark	14 131	343	3 648	12 713	1 896	12 102	715	31 976	7 210
Estonia	1 968		669	764	34	5 323		723	327
Finland	3 936	13	9 063	3 852	7 676	2 508	195	10 144	2 553
France	99 018	5 235	600 021	89 171	51 769	89 206	10 097	166 519	322 652
Germany	148 788	12 945	61 677	147 175	42 739	236 517	28 768	906 871	34 436
Greece	15 245	276	68 936	29 636	4 284	42 948	14	125 054	8 805
Hungary	7 350	0.1	2 141	6 184	5 931	52 701	401	1 114	253
Ireland	2 848	26	3 019	25 116	5 571	4 289	3 783	46 832	13 375
Italy	160 222	5 909	174 245	127 741	97 358	105 924	17 176	870 136	73 243
Latvia	6 989		5 013	483	764	14 253		1 027	544
Lithuania	13 729		12 023	939	3 735	16 704	134	11 143	4 074
Luxembourg	27	13	13	11 547	148			1 329	1 648
Malta	211		1 987	265	185	274	118	1 396	633
Netherlands	270 604	13 607	207 935	180 850	124 567	68 878	75 297	1 274 724	587 049
Poland	33 298	160	4 588	5 312	5 152	84 778		45 061	458
Portugal	15 733	334	1 642	17 724	844	1 437	925	236 168	37 016
Romania	20 965	14	19 842	1 374	19 282	188 590	7	45 752	2 960
Slovakia	2 886		4 467	1 832	1 172	12 491		202	516
Slovenia	1 952		4 026	1 841	66 227	28 253		63 651	216
Spain	70 984	4 878	178 593	214 536	12 143	40 186	43 654	566 382	42 653
Sweden	13 732	509	20 482	18 599	11 713	12 608	3 207	124 805	7 385
UK	188 875	21 279	213 762	566 715	138 621	153 316	72 866	1 055 279	574 831
EU27	1 207 587	77 176	1 641 167	1 633 474	692 715	1 655 379	400 277	7 020 722	1 969 635

*after EUROSTAT (mean for the period 2008-2010)

D. QUESTIONNAIRE TO THE 27 EU MS

National Plant Protection Organisations answers to EFSA's Bemisia questionnaire

1. Description of the data collection

In preparing scientific opinions on the pest risk assessments on *Bemisia tabaci* for the EU territory, EFSA's Plant Health Unit created a questionnaire on *B. tabaci* in MS Excel format that was sent to representatives of the National Plant Protection Organisations (NPPOs) of each of the 27 EU Member States. The aim of this request to the Member States was to confirm the pest status and the experience of measures taken against these pathogens in the EU territory in order for the Panel to provide advice based on the updated status of these viruses in the EU Member States.

The Panel acknowledges the usefulness and quality of the responses received and would like to thank all Member States for their interest and input to its current and future work.

The questionnaire on *B. tabaci* was developed in the context of the harmonised questionnaire on harmful organisms listed in EC 2000/29/EC Annex II A II. The questionnaires were harmonised to facilitate the reporting activity of the Member States by following the same support and answers structure.

Two types of answers could be provided, the first type in free text and the second type corresponding to predefined answers chosen from a list. In the latter case, guidance and rating descriptors are provided in the questionnaire itself. These tables are presented at the end.

The questionnaire on *B. tabaci* consists of seven items distributed on different sheets of an Excel file. The questionnaires were prefilled for the Member States with the following information:

- The contact details the Chief Plant Health Officer of the NPPO. This information was included in the first sheet, "Contact Details".
- Information from the European and Mediterranean Plant Protection Organisation (EPPO) Plant Quarantine data retrieval system (PQR) version 5.5.5540 (2012-01-19) consulted on 25 February 2012 (PQR database of EPPO). When information was available the relevant parts of the questionnaire were prefilled.

The questionnaires were sent out in March 2012. In this appendix, answers received up to 31 October 2012 have been considered.

Each questionnaire was checked for the consistency of its answers. If necessary, free text answers were categorised according to the ratings and their descriptors provided along with the questionnaire. All the resulting questionnaires were transferred to a single database.

5. Data analysis

The main objective of this data analysis was to collect information on the presence and prevalence of *B. tabaci* and its host plants in the EU.

The data analysis is mainly descriptive, summarising the individual information provided by the Member States.

6. Results

6.1. Response rate

Table D.1: Responses of the member states and their coverage

EU Member States	Abbreviation	Replied	
		Yes, coverage	No
Austria	AT	National	
Belgium	BE	National	
Bulgaria	BG	National	
Cyprus	CY		Missing
Czech Republic	CZ	National	
Denmark	DK	National	
Estonia	EE	National	
Finland	FI	National	
France	FR		Missing
Germany	DE	National	
Greece	GR	National	
Hungary	HU	National	
Ireland	IE	National	
Italy	IT	National	
Latvia	LV	National	
Lithuania	LT	National	
Luxembourg	LU		Missing
Malta	MT	National	
Netherlands	NL		Missing
Poland	PL		Missing
Portugal	PT		Missing
Romania	RO	National	
Slovakia	SK	National	
Slovenia	SL		Missing
Spain	ES		Missing
Sweden	SE	National	
United Kingdom	GB	National	
Total	N=27	19	8
	100%	70.4%	29.6%

The following answers will summarise the situation in 19 member states (=70.4 %) representing two thirds of the EU area and 57.1% of the total utilised land.

6.2. Pest

Table D.2: Importance of *B. tabaci* in the past, present and future

Pest relevance:	In the last ten years					Currently					Expectation for the next five years					Development		
	Total MS answers	No problems	Minimal problems	Moderate problems	Severe problems	Total MS answers	No problems	Minimal problems	Moderate problems	Severe problems	Total MS answers	NM problems	minimal problems	Moderate problems	Severe problems	Current > Past	Future > Current	Future > MAX(Current, Past)
<i>Bemisia tabaci</i>	18	22%	28%	33%	17%	18	17%	44%	28%	11%	17	12%	24%	53%	12%	2	4	2
Tomato yellow leaf curl begomovirus	16	88%	6%	0%	6%	16	88%	6%	6%	0%	12	50%	25%	25%	0%	0	5	5
Tomato chlorosis crinivirus	15	87%	13%	0%	0%	15	87%	13%	0%	0%	11	64%	36%	0%	0%	0	2	2
Tomato torrado virus	14	86%	14%	0%	0%	14	93%	7%	0%	0%	10	70%	30%	0%	0%	0	2	2
Cucurbit yellow stunting disorder crinivirus	14	100%	0%	0%	0%	14	100%	0%	0%	0%	10	80%	20%	0%	0%	0	2	2
Cucumber vein yellowing ipomovirus	14	100%	0%	0%	0%	14	100%	0%	0%	0%	10	80%	20%	0%	0%	0	2	2
Bean golden mosaic virus	14	100%	0%	0%	0%	14	100%	0%	0%	0%	9	78%	22%	0%	0%	0	2	2
Cowpea mild mottle virus	14	100%	0%	0%	0%	14	100%	0%	0%	0%	10	90%	10%	0%	0%	0	1	1
Lettuce infectious yellow virus	14	93%	7%	0%	0%	14	100%	0%	0%	0%	10	90%	10%	0%	0%	0	1	1
Peper mild tigré virus	14	100%	0%	0%	0%	14	100%	0%	0%	0%	10	90%	10%	0%	0%	0	1	1
Squash leaf curl virus	14	100%	0%	0%	0%	14	100%	0%	0%	0%	10	80%	20%	0%	0%	0	2	2
Euphorbia mosaic virus	14	100%	0%	0%	0%	14	100%	0%	0%	0%	10	80%	20%	0%	0%	0	2	2
Florida tomato virus	12	92%	8%	0%	0%	12	100%	0%	0%	0%	7	86%	14%	0%	0%	0	1	1

6.3. Relevance of the pest in time

The trend for the next five years is expected as follows

Table D.3: Importance of *B.tabaci* in each Member State: past, present and future

	In the last ten years	Currently	Expectation for the next 5 years
Great Britain	Severe problems	Severe problems	Severe problems
Greece	Severe problems	Severe problems	Severe problems
Finland	Moderate problems	Moderate problems	Moderate problems
Germany	Moderate problems	Moderate problems	Moderate problems
Hungary	Minimal problems	Moderate problems	Moderate problems
Italy	Severe problems	Moderate problems	Moderate problems
Malta	Moderate problems	Moderate problems	Moderate problems
Austria	Minimal problems	Minimal problems	Minimal problems
Belgium	Minimal problems	Minimal problems	Minimal problems
Bulgaria	Moderate problems	Minimal problems	Moderate problems
Czech Republic	Minimal problems	Minimal problems	Minimal problems
Denmark	Moderate problems	Minimal problems	Minimal problems
Estonia	No problems	Minimal problems	No problems
Ireland	Minimal problems	Minimal problems	Moderate problems
Sweden	Moderate problems	Minimal problems	Moderate problems
Latvia	No problems	No problems	Moderate problems
Lithuania	No problems	No problems	
Romania	No problems	No problems	No problems

Table D.4: Importance of Tomato chlorosis crinivirus in each Member State: past, present and future

	In the last ten years	Currently	Expectation for the next five years
Hungary	Minimal problems	Minimal problems	Minimal problems
Italy	Minimal problems	Minimal problems	Minimal problems
Austria	No problems	No problems	No problems
Belgium	No problems	No problems	No problems
Bulgaria	No problems	No problems	Minimal problems
Czech Republic	No problems	No problems	No problems
Denmark	No problems	No problems	No problems
Finland	No problems	No problems	
Germany	No problems	No problems	
Great Britain	No problems	No problems	No problems
Ireland	No problems	No problems	No problems
Latvia	No problems	No problems	Minimal problems
Lithuania	No problems	No problems	
Romania	No problems	No problems	No problems
Sweden	No problems	No problems	

Table D.5: Importance of Tomato torrado virus in each Member State: past, present and future

	In the last ten years	Currently	Expectation for the next five years
Hungary	Minimal problems	Minimal problems	Minimal problems
Austria	No problems	No problems	No problems
Belgium	Minimal problems	No problems	No problems
Czech Republic	No problems	No problems	No problems
Denmark	No problems	No problems	No problems
Finland	No problems	No problems	
Germany	No problems	No problems	
Great Britain	No problems	No problems	No problems
Ireland	No problems	No problems	No problems
Italy	No problems	No problems	Minimal problems
Latvia	No problems	No problems	Minimal problems
Lithuania	No problems	No problems	
Romania	No problems	No problems	No problems
Sweden	No problems	No problems	

Table D.6: Importance of Tomato yellow leaf curl begomovirus in each Member State: past, present and future

	In the last ten years	Currently	Expectation for the next five years
Italy	Severe problems	Moderate problems	Moderate problems
Malta	Minimal problems	Minimal problems	Moderate problems
Austria	No problems	No problems	No problems
Belgium	No problems	No problems	No problems
Bulgaria	No problems	No problems	Minimal problems
Czech Republic	No problems	No problems	No problems
Denmark	No problems	No problems	No problems
Finland	No problems	No problems	
Germany	No problems	No problems	
Great Britain	No problems	No problems	Minimal problems
Hungary	No problems	No problems	Moderate problems
Ireland	No problems	No problems	No problems
Latvia	No problems	No problems	Minimal problems
Lithuania	No problems	No problems	
Romania	No problems	No problems	No problems
Sweden	No problems	No problems	

6.4. Hosts

Table D.7: Importance of host plants in the Member States

Hosts importance ¹ :	In crop production (open air or protected cultivations, orchards or vineyards or forests)					In nurseries (for production of plant propagation material)					In private gardens, urban sites or other sites (e.g. storehouses, markets, border stations or transport)				
	Total MS answers	Absent	Only local	Only regional	Nationwide	Total MS answers	Absent	Only local	Only regional	Nationwide	Total MS answers	Absent	Only local	Only regional	Nationwide
Tomatoes	15	27%	0%	13%	60%	13	15%	38%	8%	38%	13	15%	8%	0%	77%
Cucurbitaceae	15	27%	0%	20%	53%	13	15%	38%	15%	31%	12	8%	8%	0%	83%
<i>Euphorbia pulcherrima</i> (poinsettia)	14	36%	14%	29%	21%	12	33%	33%	17%	17%	14	14%	21%	7%	57%
<i>Ficus</i>	14	50%	29%	7%	14%	11	55%	18%	9%	18%	13	15%	31%	0%	54%
<i>Hibiscus</i>	15	33%	33%	13%	20%	13	31%	46%	8%	15%	15	13%	33%	13%	40%
<i>Aster spp.</i>	14	36%	21%	14%	29%	11	45%	18%	18%	18%	13	23%	15%	8%	54%
<i>Eryngium</i>	14	36%	43%	14%	7%	11	55%	27%	9%	9%	13	23%	38%	8%	31%
<i>Gypsophila</i>	14	36%	29%	14%	21%	11	45%	36%	9%	9%	13	15%	38%	8%	38%
<i>Hypericum</i>	14	36%	36%	7%	21%	11	55%	27%	9%	9%	13	23%	31%	8%	38%
<i>Lisianthus</i>	14	43%	43%	7%	7%	11	55%	27%	9%	9%	13	23%	31%	8%	38%
<i>Rosa</i>	15	20%	7%	20%	53%	12	42%	8%	17%	33%	14	14%	7%	7%	71%
<i>Solidago</i>	14	36%	29%	14%	21%	11	55%	27%	9%	9%	13	8%	31%	15%	46%
<i>Trachelium</i>	14	43%	57%	0%	0%	11	45%	45%	0%	9%	13	23%	46%	0%	31%
<i>Ocimum</i>	14	36%	29%	14%	21%	11	27%	36%	18%	18%	14	7%	43%	7%	43%

Some Member States added to the predefined list of hosts crops the following potential hosts: ***.

6.5. Presence of the pest

Table D.8: List of pest–hosts combinations reported to be present or present in the past

Host	Region	Production type	Protection	Year of first detection	Current distribution	Remarks
<i>Bemisia tabaci</i>						
Multiple hosts	SK02: Zapadne Slovensko	Crops or orchards or forest	Protected conditions	2007	absent, pest eradicated	
Multiple hosts	DE00: DEUTSCHLAND	Crops or orchards or forest	Both open and protected		present, no details	
Multiple hosts	AT10: ÖSTÖSTERREICH	Crops or orchards or forest	Protected conditions	before 1990	present, restricted distribution	in glasshouse production only
Multiple hosts	CZ00: ČESKÁ REPUBLIKA	Crops or orchards or forest	Protected conditions	before 1990	present, restricted distribution	
Multiple hosts	BE00: BELGIQUE-BELGIË	Crops or orchards or forest	Protected conditions		present, restricted distribution	if found, mainly ornamentals
Multiple hosts	MT00: MALTA	Crops or orchards or forest	Both open and protected	1993	present, widespread	
Multiple hosts	IT00: ITALIA	Crops or orchards or forest	Both open and protected	before 1990	present, widespread	
Multiple hosts	GR00: ELLADA	Crops or orchards or forest	Both open and protected		present, widespread	
Multiple hosts	FI00: SUOMI / FINLAND	Crops or orchards or forest	Protected conditions		transient, under eradication	
Multiple hosts	CZ00: ČESKÁ REPUBLIKA	Nurseries	Protected conditions	before 1990	present, few occurrences	
Multiple hosts	DK00: DANMARK	Nurseries	Protected conditions	before 1990	present, few occurrences	
Multiple hosts	DE00: DEUTSCHLAND	Nurseries	Both open and protected		present, no details	
Multiple hosts	GR00: ELLADA	Nurseries	Both open and protected		present, no details	
Multiple hosts	UK00: UK - UNITED KINGDOM	Nurseries	Protected conditions	before 1990	transient, under eradication	Outbreaks of <i>B. tabaci</i> occur every year in a number of

Host	Region	Production type	Protection	Year of first detection	Current distribution	Remarks
						protected nurseries, but are always eradicated.
Multiple hosts	GR00: ELLADA	Private gardens/public sites	NA		present, widespread	
Multiple hosts	FI00: SUOMI / FINLAND	Several sites	NA		absent, pest eradicated	Detected in marketing control and in import inspections.
Multiple hosts	DE00: DEUTSCHLAND	Several sites	NA		present, no details	
<i>Capsicum</i>	HU33: Del-Alfold	Crops or orchards or forest	Protected conditions	1990	present, restricted distribution	
<i>Dipladenia sundaville</i>	LT00: LIETUVA	Crops or orchards or forest	Protected conditions	2007	absent, pest eradicated	1 outbreak detected during last 10 years
<i>Euphorbia pulcherrima</i> (poinsettia)	HU33: Del-Alfold	Crops or orchards or forest	Protected conditions	1990	present, restricted distribution	
<i>Euphorbia pulcherrima</i> (poinsettia)	BG41: Yugozapaden	Crops or orchards or forest	Protected conditions	2011	transient, under eradication	
<i>Euphorbia pulcherrima</i> (poinsettia)	SE00: SVERIGE	Nurseries	Protected conditions	1991	absent, pest eradicated	When Bemisia is found it has always been possible to eradicate the pest
<i>Euphorbia pulcherrima</i> (poinsettia)	EE00: EESTI	Nurseries	Protected conditions	2005	absent, pest eradicated	
<i>Hibiscus</i>	BG34: Yugoiztochen	Nurseries	Protected conditions	2011	transient, under eradication	Point of sale
Tomatoes	HU33: Del-Alfold	Crops or orchards or forest	Protected conditions	1990	present, restricted distribution	
	FI00: SUOMI / FINLAND	Nurseries	Protected conditions		absent, pest eradicated	Detected once in one nursery on poinsettias.
	BE00: BELGIQUE-	Nurseries			present, restricted	cf above

Host	Region	Production type	Protection	Year of first detection	Current distribution	Remarks
	BELGIË				distribution	
	UK00: UK - UNITED KINGDOM	Several sites	NA		present, few occurrences	<i>B. tabaci</i> is occasionally found in retail outlets and infested plants are destroyed.
Tomato chlorosis crinivirus						
Tomatoes	IT00: ITALIA	Crops or orchards or forest	Protected conditions	2000	present, restricted distribution	
Tomatoes	HU33: Del-Alfold	Crops or orchards or forest	Protected conditions	2007	present, widespread	
Tomato torrado virus						
Tomatoes	ITG1: Sicilia	Crops or orchards or forest	Protected conditions	2009	absent, pest no longer present	
Tomatoes	HU33: Del-Alfold	Crops or orchards or forest	Protected conditions	2007	present, few occurrences	
	BE00: BELGIQUE-BELGIË	Crops or orchards or forest			absent, pest eradicated	
Tomato yellow leaf curl begomovirus						
Tomatoes	ITF0: SUD	Crops or orchards or forest	Both open and protected	before 1990	present, restricted distribution	
Tomatoes	MT00: MALTA	Crops or orchards or forest	Both open and protected		present, restricted distribution	This pest was not detected throughout annual surveys performed by NPPO

NA, not available

6.6. Pest surveys

Table D.9: List of pest-hosts combinations reported to be absent, confirmed by a survey

Host	Region	Production type	Protection (open air/protected cultivation)	Year of first detection	Current distribution	Remarks
<i>Bemisia tabaci</i>						
	LV00: LATVIJA	Crops or orchards or forest			absent, confirmed by survey	
	LV00: LATVIJA	Nurseries			absent, confirmed by survey	
	LV00: LATVIJA	Several (no production) sites			absent, confirmed by survey	
	RO00: Romania	Crops or orchards or forest			absent, confirmed by survey	
	RO00: Romania	Nurseries			absent, confirmed by survey	
	RO00: Romania	Several (no production) sites			absent, confirmed by survey	
	UK00: UK - UNITED KINGDOM	Crops or orchards or forest			absent, confirmed by survey	
<i>Cucumber vein yellowing ipomovirus</i>						
	IT00: ITALIA	Crops or orchards or forest			absent, confirmed by survey	
	UK00: UK - UNITED KINGDOM	Crops or orchards or forest			absent, confirmed by survey	
	UK00: UK - UNITED KINGDOM	Nurseries			absent, confirmed by survey	Risk based surveys carried out by PHSI.
	UK00: UK - UNITED KINGDOM	Several (no production) sites			absent, confirmed by survey	
<i>Cucurbit yellow stunting disorder crinivirus</i>						
	IT00: ITALIA	Crops or orchards or forest			absent, confirmed by survey	
	UK00: UK - UNITED KINGDOM	Crops or orchards or forest			absent, confirmed by survey	
	UK00: UK - UNITED KINGDOM	Nurseries			absent, confirmed by survey	Risk based surveys

	KINGDOM					carried out by PHSI.
	UK00: UK - UNITED KINGDOM	Several (no production) sites			absent, confirmed by survey	
<i>Tomato chlorosis crinivirus</i>						
	UK00: UK - UNITED KINGDOM	Crops or orchards or forest			absent, confirmed by survey	
	UK00: UK - UNITED KINGDOM	Nurseries			absent, confirmed by survey	Risk based surveys carried out by PHSI.
	UK00: UK - UNITED KINGDOM	Several (no production) sites			absent, confirmed by survey	
<i>Tomato torrado virus</i>						
	UK00: UK - UNITED KINGDOM	Crops or orchards or forest			absent, confirmed by survey	
	UK00: UK - UNITED KINGDOM	Nurseries			absent, confirmed by survey	Risk based surveys carried out by PHSI.
	UK00: UK - UNITED KINGDOM	Several (no production) sites			absent, confirmed by survey	
<i>Tomato yellow leaf curl begomovirus</i>						
	RO00: Romania	Crops or orchards or forest			absent, confirmed by survey	
	RO00: Romania	Nurseries			absent, confirmed by survey	
	RO00: Romania	Several (no production) sites			absent, confirmed by survey	
	UK00: UK - UNITED KINGDOM	Crops or orchards or forest			absent, confirmed by survey	
	UK00: UK - UNITED KINGDOM	Nurseries			absent, confirmed by survey	Risk based surveys carried out by PHSI.
	UK00: UK - UNITED KINGDOM	Several (no production) sites			absent, confirmed by survey	

PHSI, Plant Health and Seeds Inspectorate

Table D.10: List of surveys for specific pests

Host	Region	Production type	Year of latest survey	Name of survey/control program/certification scheme	Remarks
<i>Multiple pests</i>					
Multiple hosts	BG00: BULGARIA	Multiple locations	2011	Monitoring for quarantine pests	
Multiple hosts	FI00: SUOMI / FINLAND	Multiple locations	2012	Routine survey on greenhouse production.	Attention is paid to <i>B. tabaci</i> and signs of any viral infection during the routine survey on greenhouse production, in marketing control and in import inspections. These inspections are not targeted exclusively at <i>B. tabaci</i> but also at other quarantine pests
Multiple hosts	SK00: SLOVENSKA REPUBLIKA	Multiple locations	2012	Monitoring	
Multiple hosts	HU33: Del-Alfold	Multiple locations	2012	General survey for greenhouse pests of vegetables	
<i>Bemisia tabaci</i>					
<i>Euphorbia pulcherrima</i> (poinsettia)	EE00: EESTI	Nurseries	2007	Survey of glasshouse pest 2001-2007	Production of Euphorbia pot plants for final consumers
<i>Euphorbia pulcherrima</i> (poinsettia)	FI00: SUOMI / FINLAND	Crops or orchards or forest	2011	<i>B. tabaci</i> survey targeted at greenhouses producing poinsettias.	
Multiple hosts	BG00: BULGARIA	Multiple locations	2011	Monitoring for quarantine pests	
Multiple hosts	CZ00: CESKA REPUBLIKA	Multiple locations	2012	Official surveillance	Locations: nurseries in glasshouses, imported consignments in points of entry
Multiple hosts	DK00: DANMARK	Nurseries	2012	Official plant health inspection programme, all plants for planting	
Multiple hosts	IE00: IRELAND	Multiple locations	2012	National <i>B. tabaci</i> Protected Zone survey	Interceptions at point of entry and finding in glasshouses linked to introductions
Multiple hosts	IT00: ITALIA	At borders or transport means	2010	Plant protection service activities	
Multiple hosts	LT00: LIETUVA	Multiple locations	2011	National phytosanitary control	Pest not detected
Multiple hosts	LV00: LATVIJA	Multiple locations	2011	Pests of glasshouses	
Multiple hosts	RO00: Romania	Multiple locations	2011	Monitoring plan for some quarantine pests present in	

				greenhouses	
Multiple hosts	SE00: SVERIGE	Multiple locations	2011	EU survey carried out at a yearly basis	2012 ongoing survey
Multiple hosts	UK00: UK - UNITED KINGDOM	Crops or orchards or forest	2012	Protected Zzne survey for <i>B. tabaci</i> carried out by the PHSI.	Submitted as a Protected Zone Report.
<i>Cucumber vein yellowing ipomovirus</i>					
Cucurbitaceae	ITF0: SUD	Crops or orchards or forest	2009	National project	
<i>Cucurbit yellow stunting disorder crinivirus</i>					
Cucurbitaceae	ITF0: SUD	Crops or orchards or forest	2009	National project	
<i>Tomato chlorosis crinivirus</i>					
Tomatoes	ITG0: ISOLE	Crops or orchards or forest	2010	National project	
Tomatoes	HU00: MAGYARORSZAG	Multiple locations	2012	National survey	Only in tomato growing districts
<i>Tomato torrado virus</i>					
Tomatoes	ITG1: Sicilia	Crops or orchards or forest	2009	Research programme	
Tomatoes	HU00: MAGYARORSZAG	Multiple locations	2012	National survey	Only in tomato growing districts
<i>Tomato yellow leaf curl begomovirus</i>					
Tomatoes	BE00: BELGIQUE-BELGIË	Crops or orchards or forest	2011	Cntrol program FASFC	Not detected
Tomatoes	BG00: BULGARIA	Multiple locations	2011	Monitoring for quarantine pests	
Tomatoes	ITG1: Sicilia	Crops or orchards or forest	2007	Research programme	
Tomatoes	MT00: MALTA	Multiple locations	2012	Tomato survey (testing for PepMV, TSWV, TYLCV)	This is an annual survey
Tomatoes	RO00: Romania	Multiple locations	2011	Monitoring plan for viruses on tomatoes	

PHSI, Plant Health and Seeds Inspectorate; FASFC, Federal Agency for the Safety of the Food Chain

6.7. Impact and measures per host and type of production

Table D.11: List of impact and measures applied on specific pest-hosts combinations

Host	Region	Production type	Protection	Year	Impact (Yield and/or quality loss)	Category of control measure applied	Please specify the measure applied	Effectiveness	Implementation	Remarks
<i>Bemisia tabaci</i>										
Multiple hosts	AT10: ÖSTERREICH	Crops or orchards or forest	Protected conditions	1990		Combination of measures	Biological and chemical control	High		Blümel, 1990
Multiple hosts	BE00: BELGIQUE-BELGIË	Crops or orchards or forest	Protected conditions		Minimal	Combination of measures	Chemical and biological control of vector	Moderate	At national level	Instruction of the FASFC upon finding of <i>B. tabaci</i> : blocking suspicious consignments/lots import: destruction or return consignment when presence of the organism is confirmed domestic crop production: treatment when destination of plants is a protected zone. Temporary suspension of PZ plant passport delivery.
Multiple hosts	BE00: BELGIQUE-BELGIË	Nursery	Protected conditions		Massive	Combination of measures	Biological and chemical control of vector	Moderate	At national level	Instruction of the FASFC upon finding of <i>B. tabaci</i> : blocking suspicious consignments/lotsimport: destruction or returning consignment when presence of the organism is confirmed domestic crop production: treatment when destination of plants is a protected zone. Temporary suspension of PZ plant passport delivery.
Multiple hosts	CZ00: CESKA REPUBLIKA	Crops or orchards or forest	Protected conditions		Major	Integrated pest management	The components of IPM: monitoring with sticky traps and use of insecticides	High	At national level	<i>B. tabaci</i> is managed together with <i>Trialeurodes vaporariorum</i> .

Host	Region	Production type	Protection	Year	Impact (Yield and/or quality loss)	Category of control measure applied	Please specify the measure applied	Effectiveness	Implementation	Remarks
							(active ingredient: acetamiprid, lambda-cyhalothrin or fatty acid potassium salt) and biological agents (<i>Encarsia formosa</i> , <i>Eretmocerus eremicus</i> or <i>Macrolophus caliginosus</i>)			
Multiple hosts	CZ00: CESKA REPUBLIKA	Nursery	Protected conditions		Massive	Integrated pest management	The components of IPM: monitoring with sticky traps and use of insecticides (active ingredient: acetamiprid, lambda-cyhalothrin or fatty acid potassium salt) and biological agents (<i>Encarsia formosa</i> , <i>E. retmocerus eremicus</i> or <i>Macrolophus caliginosus</i>)	High	At national level	<i>B. tabaci</i> is managed together with <i>Trialeurodes vaporariorum</i> .
Multiple hosts	DE00: DEUTSCHLAND	Crops or orchards or forest	Both open and protected		Moderate	Combination of measures	Phyotsanitary measures, pesticides, biocontrol, yellow sticky traps, import control, integrated pest	Low to moderate	At regional level only	

Host	Region	Production type	Protection	Year	Impact (Yield and/or quality loss)	Category of control measure applied	Please specify the measure applied	Effectiveness	Implementation	Remarks
							management			
Multiple hosts	DE00: DEUTSCHLAND	Nursery	Both open and protected		Moderate	Combination of measures	phytosanitary measures, pesticides, biocontrol, yellow sticky traps, import control, integrated pest management	Low to moderate	At regional level only	
Multiple hosts	DE00: DEUTSCHLAND	Several sites	NA		Moderate	Combination of measures	No systematic measures	Moderate	At regional level only	
Multiple hosts	DK00: DANMARK	Nursery	Protected conditions	Before 1990	Moderate	Phytosanitary measures	Destruction of infected lots. Chemical treatment of culture	High	At local level only	Measure only in infected nurseries
Multiple hosts	FI00: SUOMI / FINLAND	Several sites	NA		Major		The infested lots detected in marketing control or in import inspections are always destroyed.			
Multiple hosts	FI00: SUOMI / FINLAND	Crops or orchards or forest	Protected conditions		Major	Chemical pest control	Chemical control	High	At national level	
Multiple hosts	GR00: ELLADA	Crops or orchards or forest	Both open and protected	1990	Major	Chemical pest control	Mostly organophosphate, pyrethroids and neonicotinoids, also IPM in the last five years	Moderate	At national level	
Multiple hosts	GR00: ELLADA	Nursery	Both open and protected							
Multiple hosts	IE00: IRELAND	Nursery	Protected conditions		Major	Phytosanitary measures	Destruction or removal of affected parts	High	At national level	<i>B. tabaci</i> findings all linked to introductions, no finding in wider environment only in

Host	Region	Production type	Protection	Year	Impact (Yield and/or quality loss)	Category of control measure applied	Please specify the measure applied	Effectiveness	Implementation	Remarks
										protected crops
Multiple hosts	IT00: ITALIA	All production areas	NA	Before 1990	Moderate	Phytosanitary measures		Moderate	At national level	
Multiple hosts	IT00: ITALIA	Nursery	Protected conditions	Before 1990	Major	Integrated pest management	Chemical and biological control, phytosanitary measures	High	At national level	
Multiple hosts	MT00: MALTA	Crops or orchards or forest	Both open and protected	1993	Moderate	Chemical pest control	Pyrethroid applications (Delmethrin)	Moderate	At national level	
Multiple hosts	MT00: MALTA	Nursery	Both open and protected	1993	Moderate	Chemical pest control	Pyrethroid applications (Delmethrin)	Moderate	At national level	
Multiple hosts	MT00: MALTA	Several sites	NA	1993	Moderate	Chemical pest control	Pyrethroid applications (Delmethrin)	Moderate	At local level only	
Multiple hosts	SK02: Zapadne Slovensko	Crops or orchards or forest	Protected conditions	2007	Minor	Combination of measures		High	At local level only	
Multiple hosts	UK00: UK - UNITED KINGDOM	Several sites	NA	2012	Minimal	No measure / not applicable	Destruction	High	At national level	Control measures cannot be applied in stores/markets; infested plants destroyed.
Multiple hosts	UK00: UK - UNITED KINGDOM	Nursery	Protected conditions	2012	Massive	Combination of measures	A range of insecticides (including acetamiprid, spirotetmat, abamectin) and BCAs (such as <i>Eretmocerus eremicus</i>) depending on circumstances.	High	At national level	<i>B. tabaci</i> outbreaks occur regularly (every year since 199) but are all eradicated.
	FI00: SUOMI / FINLAND	Nursery	Protected conditions		Major	Chemical pest control	Chemical control	High		Detected once in one nursery on poinsettias.
	IE00: IRELAND	Crops or orchards or forest	Protected conditions		Major	Phytosanitary measures	Destruction of affected lots			

Host	Region	Production type	Protection	Year	Impact (Yield and/or quality loss)	Category of control measure applied	Please specify the measure applied	Effectiveness	Implementation	Remarks
	BG41: Yugozapaden	Crops or orchards or forest	Protected conditions	2011	Minor	Combination of measures	Eradication, chemical pest control	Moderate	At local level only	
	IT00: ITALIA	Crops or orchards or forest	Both open and protected	before 1990	Moderate	Integrated pest management	Chemical and biological control	Moderate	At national level	
	UK00: UK - UNITED KINGDOM									<i>B. tabaci</i> does not survive outdoors in the UK.
<i>Capsicum</i>	HU33: Del-Alfold	Crops or orchards or forest	Protected conditions	2012	Minor	Integrated pest management	plant hygiene +cultural control+biological control + chemicals	Moderate	At regional level only	
<i>Dipladenia sundaville</i>	LT00: LIETUVA	Crops or orchards or forest	Protected conditions	2007	Massive	Other treatments (heat, irradiation etc.)	plants with pests burned, hygiene measures	High	At national level	No more outbreaks after eradication
<i>Euphorbia pulcherrima</i> (poinsettia)	EE00: EESTI	Nursery	Protected conditions	2005	Minimal	Chemical pest control		High	At local level only	
<i>Euphorbia pulcherrima</i> (poinsettia)	HU33: Del-Alfold	Crops or orchards or forest	Protected conditions	2012	Minor	Integrated pest management	plant hygiene +cultural control+biological control + chemicals	Moderate	At regional level only	
<i>Euphorbia pulcherrima</i> (poinsettia)	SE00: SVERIGE	Nursery	Protected conditions	2011	Minor	Combination of measures	different types of chemical treatments	High	At national level	
<i>Hibiscus</i>	BG34: Yugoiztochen	Nursery	Protected conditions	2011	Minor	Combination of measures	eridication, chemical pest control	High	At local level only	
<i>Ocimum</i>	CZ00: CESKA REPUBLIKA	At borders or transport means	NA		Moderate	Phytosanitary measures	Destruction of the infested lot(s).	High	At national level	It refers to plant health checks at import.
Tomatoes	HU33: Del-Alfold	Crops or orchards or	Protected conditions	2012	Minor	Integrated pest	plant hygiene, cultural control,	Moderate	At regional level only	

Host	Region	Production type	Protection	Year	Impact (Yield and/or quality loss)	Category of control measure applied	Please specify the measure applied	Effectiveness	Implementation	Remarks
		forest				management	biological control and chemicals			
Tomato chlorosis crinivirus										
Tomatoes	HU33: Del-Alfold	Crops or orchards or forest	Protected conditions	2012	Minor	Phytosanitary measures	destruction of infected plants	Moderate	At regional level only	Yield loss is major in mixed infection with other diseases
Tomatoes	IT00: ITALIA	Fields	na	2000	Minimal	No measure / not applicable				
Tomatoes	IT00: ITALIA	Crops or orchards or forest	Protected conditions	2000	Minor	No measure / not applicable			Not implemented	
Tomatoes	IT00: ITALIA	Nursery	Protected conditions			No measure / not applicable			Not implemented	
Tomato torrado virus										
Tomatoes	BE21: Prov. Antwerpen	Crops or orchards or forest	Protected conditions	2007	Moderate	Combination of measures	Vector control and resistant varieties	High	At local level only	Only one outbreak in glasshouse, implementation indicated as local.
Tomatoes	HU33: Del-Alfold	Crops or orchards or forest	Protected conditions	2011	Minor	Phytosanitary measures	destruction of infected plants	Moderate	At regional level only	
Tomatoes	ITG1: Sicilia	Fields	na	2009	Minimal	No measure / not applicable				
Tomatoes	ITG1: Sicilia	Crops or orchards or forest	Protected conditions	2009	Minimal	No measure / not applicable			Not implemented	
Tomatoes	ITG1: Sicilia	Nursery	Protected conditions			No measure / not applicable			Not implemented	
Tomato yellow leaf curl begomovirus										
	BE00: BELGIQUE-BELGIË	Crops or orchards or forest								Instruction of the FASFC upon confirmation of this pest: inspection and sampling of other lots present/strict hygiene measures/obligatory treatment against <i>B. tabaci</i> in

Host	Region	Production type	Protection	Year	Impact (Yield and/or quality loss)	Category of control measure applied	Please specify the measure applied	Effectiveness	Implementation	Remarks
										glasshouses. Nurseries: destruction of infested material and tracing delivered lots. Production company: destruction of symptomatic plants. No data on effectiveness (no outbreaks).
	BE00: BELGIQUE-BELGIË	Nursery								Instruction of the FASFC upon confirmation of this pest: inspection and sampling of other lots present/strict hygiene measures/obligatory treatment against <i>B. tabaci</i> in glasshouses. Nurseries: destruction of infested material and tracing delivered lots. Production company: destruction of symptomatic plants. No data on effectiveness (no outbreaks).
Multiple hosts	MT00: MALTA	Several sites	NA			Chemical pest control		Moderate	At local level only	To control vectors
Tomatoes	IT00: ITALIA	Fields	NA	Before 1990	Minor	No measure / not applicable				
Tomatoes	ITF0: SUD	Crops or orchards or forest	Both open and protected	Before 1990	Major	Combination of measures	Resistant varieties; vector control	High	At national level	
Tomatoes	ITF0: SUD	Nursery	Protected conditions	Before 1990	Moderate	Phytosanitary measures	Vector control	High	At national level	
Tomatoes	MT00: MALTA	Crops or orchards or forest	Both open and protected			Chemical pest control		Moderate	At local level only	To control vectors
Tomatoes	MT00: MALTA	Nursery	Both open and protected			Chemical pest control		Moderate	At local level only	To control vectors

NA, not available; FASFC, Federal Agency for the Safety of the Food Chain

7. Ratings and descriptors used in the questionnaire

Pests	
Relevance criteria	
Relevant in the past	Outbreaks, presence, interceptions or impact in the past (last 10 years)
Currently relevant	Current outbreaks, presence, interceptions or impact
Relevant in near future	Expected outbreaks, expected presence, expected interceptions, expected impact, increasing production or trade of hosts plants in the future (next 5 years)
Categories	
Severe problems	Widespread presence and/or high impact; ineffective risk management options (i.e. phytosanitary measures and/or pest management practices)
Moderate problems	Limited distribution and/or moderate impact; ineffective or partially effective risk management options (i.e. phytosanitary measures and/or pest management practices)
Minimal problems	Few occurrences and/or low impact (due to natural enemies, competitors, effective risk management options)
No problems	Absence or decreasing presence or no impact (due to natural enemies, competitors, effective risk management options)
Hosts and vector hosts	
Categories	
Nationwide	Nationwide cultivation/occurrence/transport
Only regional	Only regional cultivation/occurrence/transport
Only local	Only local cultivation/occurrence/transport
Absent	Absence or scarce occurrence
Presence of the pests or vectors	
Categories for location	
Fields	Arable herbaceous crops (including vegetables and ornamentals) or pasture land
Orchards/vineyards/forests	Land planted with trees or other perennial woody plant (fruit trees, grapevines, forest stands etc.)
Nurseries	Sites where plant propagation material, young plants and trees are grown
Private gardens or public sites	Private or public areas where plants are grown for non-commercial purposes
Storehouses or markets	Sites devoted to the temporary storage, and market of plants and parts of plants
At borders or transport means	Sites at border or means devoted to the movement of plants and parts of plants
Categories for type of protection (open-air/protected cultivation)	
Open-air conditions	Produced under open-air conditions, including temporary protection, e.g. low tunnels
Protected conditions	Produced under permanent or semi-permanent protection structures, e.g. tunnel, greenhouses
Categories for pest distribution	
Present, no details	
Present, widespread	
Present, restricted distribution	
Present, few occurrences	
Transient, under eradication	
Absent, intercepted only	
Absent, pest eradicated	
Absent, pest no longer present	
Absent, no pest record	

Absent, confirmed by survey	
Pest and pest vector surveys	
Categories for location	
Fields	Arable herbaceous crops (including vegetables and ornamentals) or pasture land
Orchards/vineyards/forests	Land planted with trees or other perennial woody plant (fruit trees, grapevines, forest stands etc.)
Nurseries	Sites where plant propagation material, young plants and trees are grown
Private gardens or public sites	Private or public areas where plants are grown for non-commercial purposes
Storehouses or markets	Sites devoted to the temporal storage, and market of plants and parts of plants
At borders or transport means	Sites at border or means devoted to the movement of plants and parts of plants
Impact and Measures against the pests	
Categories for location	
Fields	Arable herbaceous crops (including vegetables and ornamentals) or pasture land
Orchards/vineyards/forests	Land planted with trees or other perennial woody plant (fruit trees, grapevines, forest stands etc.)
Nurseries	Sites where plant propagation material, young plants and trees are grown
Private gardens or public sites	Private or public areas where plants are grown for non-commercial purposes
Storehouses or markets	Sites devoted to the temporary storage, and market of plants and parts of plants
At borders or transport means	Sites at border or means devoted to the movement of plants and parts of plants
Categories for type of protection (open-air/protected cultivation)	
Open-air conditions	Produced under open-air conditions, including temporary protection, e.g. low tunnels
Protected conditions	Produced under permanent or semi-permanent protection structures, e.g. tunnel, greenhouses
Categories for impact	
Minimal	Effects on yield (quantity and/or quality) are not distinguishable from normal variation; no control measures are required
Minor	Yield (quantity and/or quality) is not or occasionally reduced; control measures are not necessary
Moderate	Yield (quantity and/or quality) is rarely reduced; control measures are sometimes necessary
Major	Yield (quantity and/or quality) is frequently reduced; control measures are frequently necessary
Massive	Yield (quantity and/or quality) is always reduced; control measures are always necessary
Categories for effectiveness	
Negligible	The management has no practical effect in reducing the probability of entry or establishment or spread, or the potential consequences.
Very low	The management options make it possible to reduce the probability of entry or establishment or spread, or the potential consequences, by a very little extent.
Low	The management options make it possible to reduce the probability of entry or establishment or spread, or the potential consequences, by a little extent.
Moderate	The management options make it possible to reduce the probability of entry or establishment or spread, or the potential consequences, by a moderate extent.
High	The management options make it possible to highly reduce the probability of entry or establishment or spread, or the potential consequences.
Categories of control measures	
Combination of measures	
Phytosanitary measures	

Chemical pest control	
Biological pest control	
Integrated pest management	
Other treatments (heat, irradiation etc.)	
No measure / not applicable	
Categories for implementation	
At national level	The management options are already in use in the risk assessment area as a part of the current crop management actions and / or of the existing phytosanitary measures.
At regional level only	
At local level only	
In experimental settings	
Not implemented	The management options are not in use in the risk assessment area.

E. MODELING

E.1. ARRIVAL PROBABILITY

1. The model

The model here presented allows computation of the probability of arrival of

- *B. tabaci*;
- new invasive species of *B. tabaci*;
- new circulative virus (CV);
- new non circulative virus (NV).

The model assumes that the probabilities depend on

- the macro-area from which the commodities originate: nine different macro-areas have been considered and denoted by $A_i, i = 1, 2, \dots, 9$,
- the type of commodity: three different types of commodity (plants for planting, cut flowers and branches with foliage, fruits and leafy vegetables) have been considered and denoted by $C_j, j = 1, 2, 3$.

All the probabilities of interest can be calculated for each different commodity separately or for all the commodities considered together. Below is shown how to compute the probabilities for the latter case the extension to the case of a single commodity is trivial.

Moreover, it is possible to calculate the probabilities for the whole of Europe and for the different EU countries. The results of both cases will be reported in the following.

For computational purpose, the following notation will be used

Macro-area		Commodity	
A_1	Africa – North	C_1	Plants for planting
A_2	Africa SS	C_2	Cut flowers
A_3	Asia	C_3	Fruits and leafy vegetables
A_4	Australia		
A_5	Non-EU Europe		
A_6	Near East		
A_7	North America		
A_8	Oceania		
A_9	South America		

1.1. Probability of arrival of *B. tabaci*

The probability of arrival of *B. tabaci* can be calculated as

$$P \text{ arrival of Bemisia} = \sum_{i=1}^9 \sum_{j=1}^3 P \text{ arrival of Bemisia} | \text{arrival of } C_j \text{ from } A_i \cdot P \text{ arrival of } C_j \text{ from } A_i$$

where the $P \text{ arrival of Bemisia} | \text{arrival of } C_j \text{ from } A_i$ depends on expert evaluation.

The random variable "arrival of *Bemisia*" is supposed to assume 5 possible values: very low, low, medium, high and very high. To assign a numerical meaning to these values it is supposed

- very low: the fraction of infested commodities at the arrival is in the interval $0, 0.001$,
- low: the fraction of infested commodities at the arrival is in the interval $0.001, 0.01$,
- medium: the fraction of infested commodities at the arrival is in the interval $0.01, 0.05$,
- high: the fraction of infested commodities at the arrival is in the interval $0.05, 0.2$,
- very high: the fraction of infested commodities at the arrival is in the interval $0.2, 1$.

To know the probability distribution of the variable 'arrival of *Bemisia*' it is necessary to calculate the values

$$P \text{ arrival of Bemisia} = H_k \text{ , } H_1 = \text{very low, } H_2 = \text{low, } H_3 = \text{medium, } H_4 = \text{high, } H_5 = \text{very high}$$

Denote by

- $p_{i,j}^{H_k} = P \text{ arrival of Bemisia} = H_k | \text{arrival of } C_j \text{ from } A_i$ the probability that the arrival of a *Bemisia* coming from the macro-area A_i with the commodity C_j is H_k ,
- $p_{ij}^C = P \text{ arrival of } C_j \text{ from } A_i$ the probability of arrival of C_j coming from A_i . It depends on the volume of trade, in particular $p_{ij}^C = \frac{\text{plants } C_j \text{ coming from } A_i}{\text{total plants}}$,

omitting, for sake of simplicity, H_k in the probabilities $p_{i,j}^{H_k}$,

$$P \text{ arrival of Bemisia} = H_k = \text{sum} \left(\text{diag} \begin{bmatrix} p_{11} & p_{12} & p_{13} \\ p_{21} & p_{22} & p_{23} \\ \dots & \dots & \dots \\ p_{91} & p_{92} & p_{93} \end{bmatrix} \begin{bmatrix} p_{11}^C & p_{21}^C & \dots & p_{91}^C \\ p_{12}^C & p_{22}^C & \dots & p_{92}^C \\ p_{13}^C & p_{23}^C & \dots & p_{93}^C \end{bmatrix} \right)$$

As measure of the central tendency of the probability distribution the mean is considered, while the standard deviation is used as measure of the dispersion of the data. To calculate these two indexes, the following values are chosen as representative of the different H_k :

H_k	REPRESENTATIVE VALUE
$H_1 = \text{Very low}$	0.0005
$H_2 = \text{Low}$	0.0055
$H_3 = \text{Medium}$	0.0300
$H_4 = \text{High}$	0.1250
$H_5 = \text{Very high}$	0.6000

For the purpose of the assessment the following correspondences are given

H_k	Intervals of fraction of infested commodities	Level of probability
Very low	[0 , 0.001]	Very unlikely
Low	[0.001 , 0.01]	Unlikely
Medium	[0.01 , 0.05]	Moderately likely
High	[0.05 , 0.2]	Likely
Very high	[0.2 , 1.0]	Very likely

To have an indication of the level of uncertainty the following categorisation for the standard deviation (SD) of the probability distribution of the variable "arrival of Bemisia" is used

Low	SD: 0 – 0.015
Medium	SD: 0.015 – 0.05
High	SD > 0.05

1.2. Probability of arrival of a new type of *B. tabaci*

The probability of arrival of a new type of *B. tabaci* is obtained as follows

$$P \text{ arrival of new Bemisia} = \sum_{i=1}^9 \sum_{j=1}^3 \sum_{k=1}^5 P \text{ new Bemisia} | \text{arrival of } C_j \text{ from } A_i$$

$$\cdot P \text{ arrival of Bemisia} = H_k | \text{arrival of } C_j \text{ from } A_i \cdot P \text{ arrival of } C_j \text{ from } A_i$$

that is

$$P \text{ arrival of new Bemisia} = \sum_{k=1}^5 \text{sum} \left\{ \text{diag} \left(\begin{bmatrix} P_{11}^{H_k} & P_{12}^{H_k} & P_{13}^{H_k} \\ P_{21}^{H_k} & P_{22}^{H_k} & P_{23}^{H_k} \\ \dots & \dots & \dots \\ P_{91}^{H_k} & P_{92}^{H_k} & P_{93}^{H_k} \end{bmatrix} * \begin{bmatrix} P_{11}^N & P_{12}^N & P_{13}^N \\ P_{21}^N & P_{22}^N & P_{23}^N \\ \dots & \dots & \dots \\ P_{91}^N & P_{92}^N & P_{93}^N \end{bmatrix} \begin{bmatrix} P_{11}^C & P_{21}^C & \dots & P_{91}^C \\ P_{12}^C & P_{22}^C & \dots & P_{92}^C \\ P_{13}^C & P_{23}^C & \dots & P_{93}^C \end{bmatrix} \right) \right\}$$

where $p_{i,j}^N = P$ new *Bemisia* | arrival of C_j from A_i is the probability that the *B. tabaci* coming from the macro-area A_i with commodity C_j is of a new type and it depends on expert evaluation. The symbol * denotes the product element by element of the two matrices.

1.3. Probability of arrival of new CV and new NV

A new CV or NV can arrive with *B. tabaci* or with plants. The probabilities of arrival of a new CV and new NV with *B. tabaci* and with plants are calculated separately

$$P \text{ arrival new CV with Bemisia} = \sum_{i=1}^9 \sum_{j=1}^3 P \text{ arrival new CV with Bemisia} | \text{arrival of } C_j \text{ from } A_i$$

$$P \text{ arrival of } C_j \text{ from } A_i$$

$$P \text{ arrival new CV with plant} = \sum_{i=1}^9 \sum_{j=1}^3 P \text{ arrival new CV with plant} | \text{arrival of } C_j \text{ from } A_i$$

$$P \text{ arrival of } C_j \text{ from } A_i$$

$$P \text{ arrival new NV with Bemisia} = \sum_{i=1}^9 \sum_{j=1}^3 P \text{ arrival new NV with Bemisia} | \text{arrival of } C_j \text{ from } A_i$$

$$P \text{ arrival of } C_j \text{ from } A_i$$

$$P \text{ arrival new NV with plant} = \sum_{i=1}^9 \sum_{j=1}^3 P \text{ arrival new NV with plant} | \text{arrival of } C_j \text{ from } A_i$$

$$P \text{ arrival of } C_j \text{ from } A_i$$

where

$$P \text{ arrival new CV with Bemisia} | \text{arrival of } C_j \text{ from } A_i ,$$

$$P \text{ arrival new CV with plant} | \text{arrival of } C_j \text{ from } A_i ,$$

$$P \text{ arrival new NV with Bemisia} | \text{arrival of } C_j \text{ from } A_i ,$$

and

$$P \text{ arrival new NV with plant} | \text{arrival of } C_j \text{ from } A_i ,$$

depend on expert evaluation, while $P \text{ arrival of } C_j \text{ from } A_i$ depends on the volume of trade of plants C_j in area A_i (see probability of arrival of *Bemisia* in subsection 1.1).

2. Data

To calculate the probabilities of arrival, it is necessary to know the trade matrices and the expert evaluation of the probabilities of arrival with respect to a given commodity and macro-area of origin. Here the data used for the calculation of the probabilities of arrival are summarised in different tables.

2.1. Trade data

Trade matrices for different commodities and EU countries have been reported in Appendix C (Tables C.4, C.5 and C.6).

Data on trade volume are used to compute the probability matrix:

$$\begin{bmatrix} p_{11}^C & p_{21}^C & \dots & p_{91}^C \\ p_{12}^C & p_{22}^C & \dots & p_{92}^C \\ p_{13}^C & p_{23}^C & \dots & p_{93}^C \end{bmatrix}$$

in formula (1).

2.2. Questionnaire on arrival probability

The experts in the EFSA PLH were asked to fill in a questionnaire specifically developed for the estimation of the arrival probabilities (expert knowledge elicitation). In the questionnaire the experts provided estimation of the probability of transition between the different phases of the arrival process (see Figure 1 in the Opinion). These probabilities are used in combination with data on trade volume of commodities to estimate the probability of arrival of *B. tabaci*, of new species of *B. tabaci*, and of viruses transmitted by this insect.

The matrices of probability estimation provided by the experts and necessary to calculate the probability of previous section are presented below.

Table E.1: Results of the expert's knowledge elicitation procedure for the probability of arrival of *B. tabaci*

		A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉
Very low	C ₁	0	0	0	0	0	0	0	0	0
	C ₂	0	0	0	0	0	0	0	0	0
	C ₃	0.9	0.9	0.4	1	1	0.3	0.9	1	0.8
Low	C ₁	0	0	0	0	0	0	0	0	0
	C ₂	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3	0.3
	C ₃	0.1	0.1	0.5	0	0	0.6	0.1	0	0.2
Medium	C ₁	0.3	0.3	0.3	0.3	0.3	0.2	0.3	0.3	0.3
	C ₂	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7	0.7
	C ₃	0	0	0.1	0	0	0.1	0	0	0

High	C_1	0.7	0.7	0.7	0.7	0.7	0.8	0.7	0.7	0.7
	C_2	0	0	0	0	0	0	0	0	0
	C_3	0	0	0	0	0	0	0	0	0
Very high	C_1	0	0	0	0	0	0	0	0	0
	C_2	0	0	0	0	0	0	0	0	0
	C_3	0	0	0	0	0	0	0	0	0

Table E.2: Results of the expert's knowledge elicitation procedure for the probability of arrival of new type of *B. tabaci*

	A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
C_1	0.1	0.05	0.01	0.001	0.001	0.1	0.005	0.001	0.001
C_2	0.1	0.05	0.01	0.001	0.001	0.1	0.005	0.001	0.005
C_3	0.1	0.05	0.01	0.001	0.001	0.1	0.005	0.001	0.001

Table E.3: Results of the experts knowledge elicitation procedure for the probability of arrival of new CV with *B. tabaci*

		A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
Very low	C_1	0	0	0	0	0	0	0	0	0
	C_2	0.7	0.5	0.5	1	1	0.6	1	1	0.7
	C_3	0.8	0.9	0.8	1	1	0.8	1	1	0.9
Low	C_1	0.2	0.2	0.2	0.2	0.2	0.2	0.2	0	0.2
	C_2	0.3	0.5	0.5	0	0	0.4	0	0	0.3
	C_3	0.2	0.1	0.2	0	0	0.2	0	0	0.1
Medium	C_1	0.8	0.8	0.8	0.8	0.8	0.8	0.8	0.2	0.8
	C_2	0	0	0	0	0	0	0	0	0
	C_3	0	0	0	0	0	0	0	0	0
High	C_1	0	0	0	0	0	0	0	0.8	0
	C_2	0	0	0	0	0	0	0	0	0
	C_3	0	0	0	0	0	0	0	0	0
Very high	C_1	0	0	0	0	0	0	0	0	0
	C_2	0	0	0	0	0	0	0	0	0
	C_3	0	0	0	0	0	0	0	0	0

Table E.4: Results of the experts knowledge elicitation procedure for the probability of arrival of new CV with plant

		A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉
Very low	C ₁	0.2	0.2	0.2	0.04	0.04	0.02	0.03	0.04	0.03
	C ₂	1	1	0.9	1	1	1	1	1	1
	C ₃	1	1	1	1	1	1	1	1	1
Low	C ₁	0.5	0.6	0.5	0.5	0.4	0.5	0.6	0.5	0.5
	C ₂	0	0	0.1	0	0	0	0	0	0
	C ₃	0	0	0	0	0	0	0	0	0
Medium	C ₁	0.3	0.2	0.3	0.1	0.2	0.3	0.1	0.1	0.2
	C ₂	0	0	0	0	0	0	0	0	0
	C ₃	0	0	0	0	0	0	0	0	0
High	C ₁	0	0	0	0	0	0	0	0	0
	C ₂	0	0	0	0	0	0	0	0	0
	C ₃	0	0	0	0	0	0	0	0	0
Very high	C ₁	0	0	0	0	0	0	0	0	0
	C ₂	0	0	0	0	0	0	0	0	0
	C ₃	0	0	0	0	0	0	0	0	0

Table E.5: Results of the experts knowledge elicitation procedure for the probability of arrival of new NV with *B. tabaci*.

		A ₁	A ₂	A ₃	A ₄	A ₅	A ₆	A ₇	A ₈	A ₉
Very low	C ₁	0.3	0.3	0.3	0.5	0.4	0.3	0.4	0.5	0.4
	C ₂	1	1	1	1	1	1	1	1	1
	C ₃	1	1	1	1	1	1	1	1	1
Low	C ₁	0.7	0.7	0.7	0.5	0.6	0.7	0.6	0.5	0.6
	C ₂	0	0	0	0	0	0	0	0	0
	C ₃	0	0	0	0	0	0	0	0	0
Medium	C ₁	0	0	0	0	0	0	0	0	0
	C ₂	0	0	0	0	0	0	0	0	0
	C ₃	0	0	0	0	0	0	0	0	0
High	C ₁	0	0	0	0	0	0	0	0	0
	C ₂	0	0	0	0	0	0	0	0	0
	C ₃	0	0	0	0	0	0	0	0	0
Very high	C ₁	0	0	0	0	0	0	0	0	0

	C_2	0	0	0	0	0	0	0	0	0
	C_3	0	0	0	0	0	0	0	0	0

Table E.6: Results of the experts knowledge elicitation procedure for the probability of arrival of new NV with plant.

		A_1	A_2	A_3	A_4	A_5	A_6	A_7	A_8	A_9
Very low	C_1	0.2	0.1	0	0.4	0.3	0	0.3	0.4	0.2
	C_2	1	1	1	1	1	1	1	1	1
	C_3	1	1	1	1	1	1	1	1	1
Low	C_1	0.5	0.5	0.5	0.6	0.5	0.5	0.7	0.6	0.5
	C_2	0	0	0	0	0	0	0	0	0
	C_3	0	0	0	0	0	0	0	0	0
Medium	C_1	0.3	0.4	0.5	0	0.2	0.5	0	0	0.3
	C_2	0	0	0	0	0	0	0	0	0
	C_3	0	0	0	0	0	0	0	0	0
High	C_1	0	0	0	0	0	0	0	0	0
	C_2	0	0	0	0	0	0	0	0	0
	C_3	0	0	0	0	0	0	0	0	0
Very high	C_1	0	0	0	0	0	0	0	0	0
	C_2	0	0	0	0	0	0	0	0	0
	C_3	0	0	0	0	0	0	0	0	0

3. Results

In this section the probabilities of arrival of *B. tabaci*, new CV and new NV calculated for the different EU states, with and without division for different commodities are reported. Results are obtained applying the formulae presented in Section 1. For each case a table summarizes probability distribution, mean and standard deviation.

3.1. Probabilities of arrival of *B. tabaci* for different EU countries

Table E.7: Probability distribution of the variable ‘arrival of *Bemisia*’ (columns 2-6). Mean (column 7) and Standard Deviation (column 8) of the distribution. Probability of arrival of a new type of *B. tabaci* (column 9)

	Very low	Low	Medium	High	Very High	Mean values	SD	new <i>B.tabaci</i>
Austria	0.9702	0.0232	0.0057	9.13e-04	0	0.9/1 000	0.47/1 000	0.0036
Belgium	0.7998	0.1876	0.0118	7.21e-04	0	1.9/1 000	051/1 000	0.0119
Bulgaria	0.9081	0.0780	0.0117	0.0021	0	1.5/1 000	0.44/1 000	0.0076
Cyprus	0.5433	0.2933	0.0688	0.0946	0	15.8/1 000	0.17/1 000	0.0461
Czech Republic	0.8799	0.1032	0.0159	8.59e-04	0	1.6/1 000	0.45/1 000	0.0081
Germany	0.7935	0.1888	0.0159	0.0018	0	2.1/1 000	0.51/1 000	0.0097
Denmark	0.7675	0.1990	0.0269	0.0066	0	3.1/1 000	0.52/1 000	0.0136
Estonia	0.8445	0.1351	0.0204	0	0	1.8/1 000	0.46/1 000	0.0118
Spain	0.8188	0.1692	0.0086	0.0034	0	2.0/1 000	0.49/1 000	0.0202
Finland	0.7167	0.2541	0.0291	1.17e-04	0	2.6/1 000	0.62/1 000	0.0469
France	0.8383	0.1498	0.0110	8.78e-04	0	1.7/1 000	0.47/1 000	0.0579
UK	0.8126	0.1756	0.0115	2.85e-04	0	1.8/1 000	0.50/1 000	0.0235
Greece	0.8371	0.1556	0.0068	4.94e-04	0	1.5/1 000	0.48/1 000	0.0279
Hungary	0.8650	0.1084	0.0203	0.0063	0	2.4/1 000	0.44/1 000	0.0128
Ireland	0.8163	0.1741	0.0084	0.0011	0	1.8/1 000	0.49/1 000	0.0166
Italy	0.7662	0.2137	0.0173	0.0029	0	2.4/1 000	0.54/1 000	0.0209
Lithuania	0.7628	0.2085	0.0282	5.51e-04	0	2.4/1 000	0.54/1 000	0.0312
Luxembourg	0.8830	0.1145	0.0016	9.23e-04	0	1.2/1 000	0.46/1 000	0.0108
Latvia	0.8089	0.1637	0.0269	5.39e-04	0	2.2/1 000	0.49/1 000	0.0238
Malta	0.8374	0.1547	0.0078	4.27e-05	0	1.5/1 000	0.48/1 000	0.0501
Netherlands	0.7542	0.1975	0.0317	0.0167	0	4.5/1 000	0.54/1 000	0.0237
Poland	0.8102	0.1667	0.0226	6.19e-04	0	2.1/1 000	0.49/1 000	0.0083
Portugal	0.7976	0.1962	0.0056	5.61e-04	0	1.7/1 000	0.52/1 000	0.0083
Romania	0.8725	0.1123	0.0140	0.0012	0	1.6/1 000	0.45/1 000	0.0151
Sweden	0.7832	0.2040	0.0122	5.51e-04	0	1.9/1 000	0.53/1 000	0.0186
Slovenia	0.6319	0.3244	0.0417	0.0019	0	3.6/1 000	0.81/1 000	0.0431
Slovakia	0.8608	0.1218	0.0174	4.98e-05	0	1.6/1 000	0.45/1 000	0.0272
Europe	0.7991	0.1803	0.0164	0.0042	0	2.4/1 000	0.50/1 000	0.0221

3.2. Probabilities of arrival of a new CV with *B. tabaci* for different EU countries

Table E.8: Probability distribution of the variable ‘arrival of a new CV with *Bemisia*’ (columns 2-6). Mean of the distribution (column 7)

	Very low	Low	Medium	High	Very High	Mean values
Austria	0.7634	0.1998	0.0280	0.0088	0	3.4/1 000
Belgium	0.6240	0.3027	0.0571	0.0162	0	5.7/1 000
Bulgaria	0.6831	0.2052	0.0797	0.0318	0	7.8/1 000
Cyprus	0.2788	0.2088	0.4344	0.0780	0	24.1/1 000
Czech Republic	0.6498	0.2009	0.0967	0.0527	0	10.9/1 000
Germany	0.6108	0.2539	0.0951	0.0403	0	9.6/1 000
Denmark	0.5410	0.2526	0.1367	0.0698	0	14.5/1 000
Estonia	0.5614	0.2007	0.1508	0.0871	0	16.8/1 000
Spain	0.5562	0.2564	0.1482	0.0392	0	11/1 000
Finland	0.3348	0.2411	0.3619	0.0621	0	20.1/1 000
France	0.2792	0.2946	0.3569	0.0694	0	21.1/1 000
UK	0.5427	0.3058	0.1191	0.0324	0	9.6/1 000
Greece	0.5056	0.2491	0.2013	0.0440	0	13.2/1 000
Hungary	0.6294	0.1931	0.1364	0.0411	0	10.6/1 000
Ireland	0.6161	0.2928	0.0773	0.0138	0	6/1 000
Italy	0.5152	0.2611	0.1740	0.0497	0	13.1/1 000
Lithuania	0.3782	0.2219	0.2928	0.1070	0	23.6/1 000
Luxembourg	0.7350	0.2535	0.0106	8.12e-004	0	2.2/1 000
Latvia	0.4374	0.1870	0.2623	0.1133	0	23.3/1 000
Malta	0.3464	0.2733	0.3244	0.0558	0	18.4/1 000
Netherlands	0.4947	0.3117	0.1494	0.0442	0	12/1 000
Poland	0.5812	0.2073	0.1345	0.0769	0	15.1/1 000
Portugal	0.6296	0.3181	0.0317	0.0207	0	5.6/1 000
Romania	0.6188	0.2122	0.1343	0.0346	0	9.8/1 000
Sweden	0.5547	0.2659	0.01440	0.0354	0	6.6/1 000
Slovenia	0.4126	0.2375	0.3428	0.0071	0	12.7/1 000
Slovakia	0.5011	0.1973	0.2337	0.0679	0	16.8/1 000
Europe	0.5336	0.2822	0.01448	0.0393	0	7.2/1 000

3.3. Probabilities of arrival of a new CV with plant for different EU countries

Table E.9: Probability distribution of the variable ‘arrival of a new CV with plant’ (columns 2-6). Mean of the distribution (column 7)

	Very low	Low	Medium	High	Very high	Mean values
Austria	0.9987	1.75e-006	2.61e-004	0.0010	0	0.6/1 000
Belgium	0.9990	1.47e-007	2.03e-004	8.13e-004	0	0.6/1 000
Bulgaria	0.9969	4.50e-008	6.11e-004	0.0024	0	0.8/1 000
Cyprus	0.8789	3.96e-007	0.0242	0.0969	0	13.3/1 000
Czech Republic	0.9988	2.35e-006	2.39e-004	9.57e-004	0	0.6/1 000
Germany	0.9974	2.67e-006	5.21e-004	0.0021	0	0.8/1 000
Denmark	0.9906	3.90e-008	0.0019	0.0075	0	1.5/1 000
Estonia	1	0	0	0	0	0.5/1 000
Spain	0.9951	8.11e-007	9.76e-004	0.0039	0	1/1 000
Finland	0.9998	0	3.15e-005	1.26e-004	0	0.5/1 000
France	0.9987	1.71e-006	2.49e-004	9.98e-004	0	0.6/1 000
UK	0.9996	9.94e-006	8.09e-005	3.24e-004	0	0.5/1 000
Greece	0.9993	2.84e-006	1.40e-004	5.61e-004	0	0.6/1 000
Hungary	0.9909	1.36e-005	0.0018	0.0072	0	1.4/1 000
Ireland	0.9985	6.30e-008	3.05e-004	0.0012	0	0.7/1 000
Italy	0.9960	1.83e-006	8.07e-004	0.0032	0	0.9/1 000
Lithuania	0.9992	0	1.57e-004	6.27e-004	0	0.6/1 000
Luxembourg	0.9987	0	2.64e-004	0.0011	0	0.6/1 000
Latvia	0.9992	0	1.54e-004	6.16e-004	0	0.6/1 000
Malta	0.9999	0	1.18e-005	4.73e-005	0	0.5/1 000
Netherlands	0.9762	3.46e-005	0.0048	0.0190	0	3/1 000
Poland	0.9991	1.78e-005	1.74e-004	6.95e-004	0	0.6/1 000
Portugal	0.9992	0	1.60e-004	6.40e-004	0	0.6/1 000
Romania	0.9983	4.34e-007	3.43e-004	0.0014	0	0.7/1 000
Sweden	0.9992	1.25e-007	1.57e-004	6.29e-004	0	0.6/1 000
Slovenia	0.9974	4.00e-008	5.22e-004	0.0021	0	0.8/1 000
Slovakia	0.9999	0	1.41e-005	5.66e-005	0	0.5/1 000
Europe	0.9940	8.96e-006	0.0012	0.0048	0	1.1/1 000

3.4. Probabilities of arrival of a new NV with *B. tabaci* for different EU countries

Table E.10: Probability distribution of the variable ‘arrival of a new NV with *Bemisia*’ (columns 2-6). Mean of the distribution (column 7)

	Very low	Low	Medium	High	Very high	Mean values
Austria	0.8631	0.1167	0.0202	0	0	1.7/1 000
Belgium	0.7079	0.2485	0.0436	0	0	3/1 000
Bulgaria	0.7892	0.1541	0.0567	0	0	2.9/1 000
Cyprus	0.3540	0.2793	0.3666	0	0	12.7/1 000
Czech Republic	0.7554	0.1801	0.0645	0	0	3.3/1 000
Germany	0.7107	0.2276	0.0617	0	0	3.5/1 000
Denmark	0.6425	0.2706	0.0869	0	0	4.4/1 000
Estonia	0.6833	0.2333	0.0834	0	0	4.1/1 000
Spain	0.6298	0.2947	0.0756	0	0	4.2/1 000
Finland	0.3966	0.3519	0.2515	0	0	9.7/1 000
France	0.3187	0.5053	0.1759	0	0	8.2/1 000
UK	0.6052	0.3169	0.0778	0	0	4.4/1 000
Greece	0.5781	0.3243	0.0977	0	0	5/1 000
Hungary	0.7287	0.1652	0.1061	0	0	4.5/1 000
Ireland	0.6766	0.2630	0.0604	0	0	3.6/1 000
Italy	0.6055	0.2826	0.1119	0	0	5.2/1 000
Lithuania	0.4889	0.3392	0.1720	0	0	7.3/1 000
Luxembourg	0.7447	0.2454	0.0099	0	0	2/1 000
Latvia	0.5619	0.2927	0.1454	0	0	6.3/1 000
Malta	0.3941	0.4465	0.1594	0	0	7.4/1 000
Netherlands	0.5716	0.3260	0.1023	0	0	5.1/1 000
Poland	0.7095	0.2033	0.0871	0	0	4.1/1 000
Portugal	0.7212	0.2592	0.1951	0	0	7.6/1 000
Romania	0.7181	0.1881	0.0938	0	0	4.2/1 000
Sweden	0.6402	0.2671	0.0927	0	0	4.6/1 000
Slovenia	0.4713	0.1979	0.3308	0	0	11.2/1 000
Slovakia	0.5916	0.2749	0.1334	0	0	5.8/1 000
Europe	0.6112	0.2985	0.0903	0	0	4.7/1 000

3.5. Probabilities of arrival of a new NV with plant for different EU countries

Table E.11: Probability distribution of the variable ‘arrival of a new NV with plant’ (columns 2-6). Mean of the distribution (column 7)

	Very low	Low	Medium	High	Very high	Mean values
Austria	0.9987	0	2.61e-004	0.0010	0	0.6/1 000
Belgium	0.9990	0	2.03e-004	8.13e-004	0	0.6/1 000
Bulgaria	0.9969	0	6.11e-004	0.0024	0	0.8/1 000
Cyprus	0.8789	0	0.0242	0.00969	0	2.4/1 000
Czech Republic	0.9988	0	2.39e-004	9.57e-004	0	0.6/1 000
Germany	0.9974	0	5.21e-004	0.0021	0	0.8/1 000
Denmark	0.9906	0	0.0019	0.0075	0	1.5/1 000
Estonia	1	0	0	0	0	0.5/1 000
Spain	0.9951	0	9.76e-004	0.0039	0	1/1 000
Finland	0.9998	0	3.15e-005	1.26e-004	0	0.5/1 000
France	0.9987	0	2.49e-004	9.98e-004	0	0.6/1 000
UK	0.9996	0	8.09e-005	3.24e-004	0	0.5/1 000
Greece	0.9993	0	1.40e-004	5.61e-004	0	0.6/1 000
Hungary	0.9910	0	0.0018	0.0072	0	1.4/1 000
Ireland	0.9985	0	3.05e-004	0.0012	0	0.7/1 000
Italy	0.9960	0	8.07e-004	0.0032	0	0.9/1 000
Lithuania	0.9992	0	1.57e-004	6.27e-004	0	0.6/1 000
Luxembourg	0.9987	0	2.64e-004	0.0011	0	0.6/1 000
Latvia	0.9992	0	1.54e-004	6.16e-004	0	0.6/1 000
Malta	0.9999	0	1.18e-005	4.73e-005	0	0.5/1 000
Netherlands	0.9762	0	0.0048	0.0190	0	3/1 000
Poland	0.9991	0	1.74e-004	6.95e-004	0	0.6/1 000
Portugal	0.9992	0	1.60e-004	6.40e-004	0	0.6/1 000
Romania	0.9983	0	3.43e-004	0.0014	0	0.7/1 000
Sweden	0.9992	0	1.57e-004	6.29e-004	0	0.6/1 000
Slovenia	0.9974	0	5.22e-004	0.0021	0	0.8/1 000
Slovakia	0.9999	0	1.41e-005	5.66e-005	0	0.5/1 000
Europe	0.9941	0	0.0012	0.0048	0	1.1/1 000

In the following tables the probability of arrival of *B. tabaci* for different commodities is reported.

3.6. Probabilities of arrival of *B. tabaci* for different EU countries (Commodity C1: Plants for planting)

Table E.12: Probability distribution of the variable ‘arrival of *Bemisia*’ on Plants for planting (columns 2-6). Mean (column 7) and Standard Deviation (column 8) of the distribution. Probability of arrival of a new type of *B. tabaci* (column 9)

	Very low	Low	Medium	High	Very high	mean values	SD	new <i>B.tabaci</i>
Austria	0	0	0.2998	0.7002	0	96.5/1 000	43.5/1 000	0.0013
Belgium	0	0	0.2908	0.7092	0	97.4/1 000	43.1/1 000	0.0248
Bulgaria	0	0	0.2998	0.7002	0	96.5/1 000	43.5/1 000	0.0015
Cyprus	0	0	0.2190	0.7810	0	104.2/1 000	39.3/1 000	0.0833
Czech Republic	0	0	0.2822	0.7178	0	98.2/1 000	42.8/1 000	0.0253
Germany	0	0	0.2935	0.7065	0	97.1/1 000	43.3/1 000	0.0266
Denmark	0	0	0.3	0.7	0	96.5/1 000	43.5/1 000	0.0071
Estonia	0	0	0	0	0	0	0	0
Spain	0	0	0.2998	0.7002	0	96.5/1 000	43.5/1 000	0.0342
Finland	0	0	0.2561	0.7439	0	100.7/1 000	41.5/1 000	0.0500
France	0	0	0.2967	0.7033	0	96.8/1 000	43.4/1 000	0.0419
UK	0	0	0.2959	0.7041	0	96.9/1 000	43.4/1 000	0.0117
Greece	0	0	0.2958	0.7042	0	96.9/1 000	43.4/1 000	0.0069
Hungary	0	0	0.2985	0.7015	0	96.6/1 000	43.5/1 000	0.0050
Ireland	0	0	0.2508	0.7492	0	101.2/1 000	41.2/1 000	0.0504
Italy	0	0	0.2913	0.7087	0	97.3/1 000	43.2/1 000	0.0231
Lithuania	0	0	0.2973	0.7027	0	96.8/1 000	43.4/1 000	0.0125
Luxembourg	0	0	0.3	0.7	0	96.5/1 000	43.5/1 000	0.0499
Latvia	0	0	0.2994	0.7006	0	96.6/1 000	43.5/1 000	0.0054
Malta	0	0	0.2778	0.7222	0	98.6/1 000	42.6/1 000	0.0250
Netherlands	0	0	0.2993	0.7007	0	96.6/1 000	43.5/1 000	0.0098
Poland	0	0	0.2877	0.7123	0	97.7/1 000	43/1 000	0.0180
Portugal	0	0	0.2996	0.7004	0	96.5/1 000	43.5/1 000	0.0172
Romania	0	0	0.3	0.7	0	96.5/1 000	43.5/1 000	0.0013
Sweden	0	0	0.2998	0.7002	0	96.5/1 000	43.5/1 000	0.0028
Slovenia	0	0	0.2542	0.7458	0	100.8/1 000	41.4/1 000	0.0464
Slovakia	0	0	0.2960	0.7040	0	96.9/1 000	43.4/1 000	0.0176
Europe	0	0	0.2963	0.7037	0	96.9/1 000	43.4/1 000	0.0154

3.7. Probabilities of arrival of *B. tabaci* for different EU countries (Commodity C2: Cut flowers)

Table E.13: Probability distribution of the variable ‘arrival of *Bemisia*’ on Cut flowers (columns 2-6). Mean (column 7) and Standard Deviation (column 8) of the distribution. Probability of arrival of a new type of *B. tabaci* (column 9)

	Very low	Low	Medium	High	Very high	mean values	SD	new <i>B.tabaci</i>
Austria	0	0	0.3	0.7	0	22.7/1 000	11.3/1 000	0.0014
Belgium	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0013
Bulgaria	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0952
Cyprus	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0983
Czech Republic	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0652
Germany	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0153
Denmark	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0011
Estonia	0	0	0	0	0	0	0	0
Spain	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0135
Finland	0	0	0	0	0	0	0	0
France	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0550
UK	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0498
Greece	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0118
Hungary	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0372
Ireland	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0012
Italy	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0310
Lithuania	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.1000
Luxembourg	0	0	0	0	0	0	0	0
Latvia	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.1
Malta	0	0	0	0	0	0	0	0
Netherlands	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0194
Poland	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0176
Portugal	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0125
Romania	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0316
Sweden	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0179
Slovenia	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0649
Slovakia	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0050
Europe	0	0.3	0.7	0	0	22.7/1 000	11.3/1 000	0.0185

3.8. Probabilities of arrival of *B. tabaci* for different EU countries (Commodities C3: Fruits and leafy vegetables)

Table E.14: Probability distribution of the variable ‘arrival of *Bemisia*’ on Fruits and leafy vegetables (columns 2-6). Mean (column 7) and Standard Deviation (column 8) of the distribution. Probability of arrival of a new type of *B. tabaci* (column 9)

	Very low	Low	Medium	High	Very high	mean values	SD	new <i>B. tabaci</i>
Austria	0.9743	0.0224	0.0033	0	0	0.71/1 000	1.8/1 000	0.0036
Belgium	0.8058	0.1871	0.0071	0	0	1.65/1 000	3.1/1 000	0.0119
Bulgaria	0.9110	0.0783	0.0107	0	0	1.21/1 000	3.3/1 000	0.0076
Cyprus	0.6190	0.3337	0.0473	0	0	3.56/1 000	6.3/1 000	0.0409
Czech Republic	0.8814	0.1033	0.0153	0	0	1.47/1 000	3.9/1 000	0.0081
Germany	0.7995	0.1887	0.0118	0	0	1.79/1 000	3.7/1 000	0.0096
Denmark	0.7810	0.2001	0.0189	0	0	2.06/1 000	4.4/1 000	0.0137
Estonia	0.8445	0.1351	0.0204	0	0	1.78/1 000	4.4/1 000	0.0118
Spain	0.8229	0.1700	0.0071	0	0	1.56/1 000	3/1 000	0.0201
Finland	0.7168	0.2541	0.0291	0	0	2.63/1 000	5.2/1 000	0.0469
France	0.8395	0.1500	0.0105	0	0	1.56/1 000	3.4/1 000	0.0579
UK	0.8135	0.1756	0.0109	0	0	1.7/1 000	3.5/1 000	0.0234
Greece	0.8378	0.1556	0.0066	0	0	1.47/1 000	2.9/1 000	0.0279
Hungary	0.8733	0.1093	0.0174	0	0	1.56/1 000	4.1/1 000	0.0129
Ireland	0.8176	0.1744	0.0080	0	0	1.61/1 000	3.2/1 000	0.0166
Italy	0.7697	0.2145	0.0158	0	0	2.04/1 000	4.1/1 000	0.0209
Lithuania	0.7634	0.2086	0.0280	0	0	2.37/1 000	5.1/1 000	0.0312
Luxembourg	0.8841	0.1147	0.0012	0	0	1.11/1 000	1.9/1 000	0.0107
Latvia	0.8095	0.1638	0.0267	0	0	2.11/1 000	5/1 000	0.0238
Malta	0.8375	0.1547	0.0078	0	0	1.5/1 000	3.1/1 000	0.0501
Netherlands	0.7852	0.2007	0.0141	0	0	1.91/1 000	3.9/1 000	0.0241
Poland	0.8119	0.1666	0.0215	0	0	1.97/1 000	4.5/1 000	0.0083
Portugal	0.7983	0.1964	0.0053	0	0	1.64/1 000	2.9/1 000	0.0083
Romania	0.8740	0.1125	0.0135	0	0	1.46/1 000	3.7/1 000	0.0151
Sweden	0.7839	0.2042	0.0119	0	0	1.87/1 000	3.7/1 000	0.0186
Slovenia	0.6337	0.3253	0.0410	0	0	3.34/1 000	6/1 000	0.0431
Slovakia	0.8611	0.1217	0.0172	0	0	1.62/1 000	4.1/1 000	0.0272
Europe	0.8075	0.1809	0.0117	0	0	1.75/1 000	3.6/1 000	0.0222

As exemplification the probability distributions for the three commodities relative to Europe are illustrated in Figure E.1.

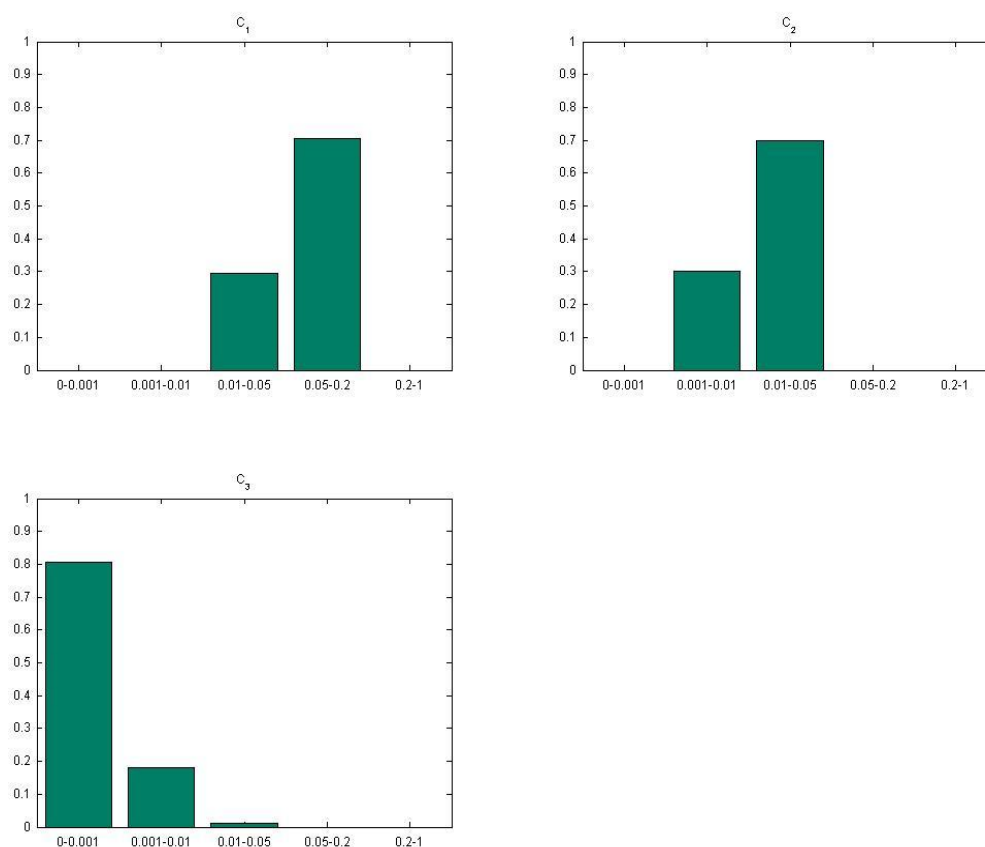


Figure E.1: Histograms of the probability distributions of arrival of *B. tabaci* for the three different commodities

3.9. Probabilities of arrival of new viruses

Concerning the probabilities of arrival of new viruses, for sake of simplicity, only results for the whole Europe are reported, for the different commodities.

Table E.15: Arrival probabilities of virus for the whole Europe (Commodity C1: Plants for planting)

	Very low	Low	Medium	High	Very high	Mean values	SD
CV with <i>B. tabaci</i>	0	0.1998	0.7994	0.0008	0	25/1 000	10/1 000
CV with plant	0.2606	0.5202	0.2192	0	0	9.6/1 000	11/1 000
NV with <i>B. tabaci</i>	0.3551	0.6449	0	0	0	3.7/1 000	2.4/1 000
NV with plant	0.1488	0.5382	0.3130	0	0	12/1 000	12/1 000

Table E.16: Arrival probabilities of virus for the whole Europe (Commodity C2: Cut flowers)

	Very low	Low	Medium	High	Very high	Mean values	SD
CV with <i>B. tabaci</i>	0.8483	0.1517	0	0	0	1.3/1 000	1.8/1 000
CV with plant	0.9980	0.0020	0	0	0	0.5/1 000	0.2/1 000
NV with <i>B. tabaci</i>	1	0	0	0	0	0.5/1 000	0
NV with plant	1	0	0	0	0	0.5/1 000	0

Table E.17: Arrival probabilities of virus for the whole Europe (Commodity C3: Fruits and leafy vegetables)

	Very low	Low	Medium	High	Very high	Mean values	SD
CV with <i>B. tabaci</i>	0.9014	0.0986	0	0	0	0.99/1 000	1.5/1 000
CV with plant	1	0	0	0	0	0.5/1 000	0
NV with <i>B. tabaci</i>	1	0	0	0	0	0.5/1 000	0
NV with plant	1	0	0	0	0	0.5/1 000	0

E.2. BEMISIA TABACI POPULATION DYNAMICS MODEL

B. tabaci population is considered as stage-structured population, in which two stages are present: immature and reproductive adults. The population dynamics of *B. tabaci* is described through von Foerster equations (Di Cola et al., 1999). The model requires the knowledge of the temperature-dependent biodemographic rate functions: development, mortality and fecundity. These functions depend on the main external forcing variable, namely the temperature. Density-dependent regulation is introduced by an additional mortality component related to the local (i.e. node) population abundance.

We consider a grid in the space, with square cells 25 km × 25 km, covering the whole of Europe. In each node of the grid the model output is described by two variables:

- *B. tabaci* presence or availability (*BA*),
- *B. tabaci* population pressure (*BP*).

B. tabaci presence is the fraction of the year in which abundance of *B. tabaci* adults is above a given threshold. This threshold has been set equal to one individual per plant. *B. tabaci* population pressure is the average adult abundance in the period of *B. tabaci* availability.

1. Data for parameter estimation

Parameters in the biodemographic functions have been estimated on the basis of experimental data on life history traits collected at individual level and available in literature. Many references consider the dependence of life history traits on temperature as well as on host plant. However, most of them do not report any information on the biotype or species of the tested population. The necessity to differentiate the biodemographic responses of MEAM1 and Med species (formerly known as B and Q biotypes) limited the papers to be considered to those in which the taxonomic identity of the experimental population is clearly determined and reported. The following papers were taken into account for parameter estimation: Bayan et al. (2006a); Bonato et al. (2007); Brewster et al. (1997); Chen et al. (2003); Crowder et al. (2006); De Barro et al. (2006); Oriani de Godoy et al. (2011); Delatte et al. (2009); Deschamps and Bonato (2011); Elbaz et al. (2011); Gergis (1994); Gonzalez-Zamora and Moreno (2011); Guo et al. (2012); Iida et al. (2009); Kakimoto et al. (2007); Li et al. (2012b); Mansaray and Sundufu (2009); Muñiz and Nombela (2001); Musa and Ren (2005); Nava-Camberos et al. (2001); Naranjo and Ellsworth (2005); Naranjo and Ellsworth (2009); Naranjo et al. (2010); Pascual and Callejas (2004); Qiu et al. (2004); Tsai and Wang (1996); Tsueda and Tsuchida (2011); Wagner (1995); Walker et al. (2010); Yang and Chi (2006); Xie et al. (2011); Zang and Liu (2007).

2. Development rate function

Different development rate functions have been reported for *B. tabaci* in literature. Considering the most recent papers, Bonato et al. (2007) used a Logan function for the development rate function of *B. tabaci* (Q biotype), while in Muñiz and Nombela (2001) the development rate function of *B. tabaci* (B and Q species) was described using a Lactin function. For the functional form of the Logan and Lactin functions see Kontodimas et al. (2004). Here, the development rate function is modelled using the function proposed by Brière et al. (1999) because of the advantages it offers in term of interpolation of the experimental data

$$\sigma(T) = aT \frac{T - T_{\min}}{\sqrt{T_{\max} - T}}$$

Data collected in literature are fitted using the function $\sigma(T)$. The estimated parameters a , T_{\min} , T_{\max} for the two stages (immatures and adults) are reported below.

IMMATURES

The best fit is obtained using the parameters reported in Table E.18.

Table E.18: Parameters of the immature development rate function for Med and MEAM1 species

	a	T_{\min} (°C)	T_{\max} (°C)
Med	0.00003588	11.11	37.61
MEAM1	0.00003549	9.87	37.02

The development rate functions obtained for the two species Med and MEAM1 are very similar.

ADULTS

The best fit is obtained using the parameters reported in Table E.19.

Table E.19: Parameters of the adults development rate function for the Med and MEAM1 species

	a	T_{\min} (°C)	T_{\max} (°C)
Med	0.00003888	7.35	40
MEAM1	0.0000313	4.45	40

For adults the estimated development functions for the two species are also quite similar. Here the development has to be interpreted in term of aging and define the maximum lifespan of the adults.

3. Mortality rate function

A finite survival rate function of the type

$$sur(T) = p_1 T^2 + p_2 T + p_3$$

is considered, where p_1, p_2, p_3 are constants that have to be estimated. To account for the density dependent regulation of the *B. tabaci* population the mortality rate function is defined as follows:

$$m(T) = 0.03 + \begin{cases} \mu T & \text{if } N t \geq 10000 \\ \mu T \cdot 0.6 \log N t - 10000 + 1 & \text{if } N t > 10000 \end{cases}$$

where $N t$ is the total population at time t per spatial unit (single plant) and

$$\mu(T) = \begin{cases} -\sigma(T) \cdot \log(\text{sur}(T)) & \text{for } T \in [T_{\text{inf}}, T_{\text{sup}}] \\ \frac{c_1}{T_{\text{inf}}} T^2 - 2c_1 T + 0.1 & \text{for } T < T_{\text{inf}} \\ c_2 T^2 - 2c_2 T_{\text{sup}} T + d_2 & \text{for } T > T_{\text{sup}} \end{cases}$$

with

$$c_1 = \frac{1}{T_{\text{inf}}} \left[0.1 + \sigma T_{\text{inf}} \log \text{sur } T_{\text{inf}} \right]$$

$$c_2 = \frac{0.1 + \sigma T_{\text{sup}} \log \text{sur } T_{\text{sup}}}{2500 - 100T_{\text{sup}} + T_{\text{sup}}^2} \quad d_2 = -\sigma T_{\text{sup}} \log \text{sur } T_{\text{sup}} + c_2 T_{\text{sup}}^2$$

σT is the development rate function above described.

The mortality rate function is defined piecewise. In the interval $[T_{\text{inf}}, T_{\text{sup}}]$ the definition depends on the development rate function. Outside this interval the mortality rate is a function that increases as the temperature increases (for $T > T_{\text{sup}}$) or decreases (for $T < T_{\text{inf}}$).

The survival and mortality rate functions for immatures and adults are obtained by fitting literature data. The best fit of immature survival is obtained using the values of parameters of survival function indicated in Tab. E.20. The best fit of adult survival is obtained using the values of parameters of survival function indicated in Tab. E.21.

Table E.20: Parameters of survival function for immatures of Med and MEAM1 species

	p_1	p_2	p_3
Med	-0.00198	0.0919	-0.4702
MEAM1	-0.002265	0.1076	-0.6149

Table E.21: Parameters of survival function for adults of Med and MEAM1 species

	p_1	p_2	p_3
Med	-0.001464	0.066	-0.402
MEAM1	-0.001952	0.088	-0.536

The values of $T_{\text{inf}}, T_{\text{sup}}$ are the same for Med and MEAM1, but different for immatures and adults. For immatures $T_{\text{inf}} = 10, T_{\text{sup}} = 37.02$, while for adults $T_{\text{inf}} = 7.4, T_{\text{sup}} = 40$.

4. Fecundity

The number of eggs for female is represented by the function (Gutierrez and Ponti, 2012)

$$fec\ T = \alpha \max \left(1 - \left(\frac{T - T_{\min} - T_{mid}}{T_{mid}} \right)^2, 0 \right)$$

where $\alpha, T_{\min}, T_{mid}$ are constants that have to be estimated.

By fitting literature data we obtain the parameters in Table E.22.

Table E.22: Parameters of the fecundity functions for Med and MEAM1 species.

	α	T_{\min}	T_{mid}
Med	105.42	14.08	10.96
MEAM1	144.04	13.48	11.01

5. Modelling variability

Literature data on development, survival and fecundity temperature-dependent rates of *B. tabaci* are affected by biological variability and heterogeneity characterising different experimental datasets. The effect of variability in biodemographic rates on the population dynamics of *B. tabaci* has been assessed considering a stochastic extension of the demographic model of *B. tabaci*. In the stochastic model confidence bands for the biodemographic functions have been introduced. The variability in biodemographic functions is related to the experimental variability.

A large number of simulations of population dynamics has been performed randomly choosing, for each simulation, biodemographic rate functions within the respective confidence bands. This analysis has been conducted in three different nodes: near Malaga (Spain), where *B. tabaci* is present with high population pressure; Pianura Padana (Italy), where *B. tabaci* is present with medium population pressure; and near London (UK), where *B. tabaci* is not present. The study shows that the London remains pest free, while the variability of *B. tabaci* population pressure and of *B. tabaci* probability of establishment in the Malaga and Pianura Padana can be considered low.

E.3. EXPLORATION OF CLIMATIC SCENARIOS

Climate scenarios are frequently used for the analysis of biological and ecological systems responses to change in environmental forcing variables. Nevertheless, projections carried out using General circulation models (GCMs) are subject to inaccuracies of different kind. Hence, in order to avoid the uncertainties resulting from these inaccuracies, a simpler approach has been adopted based on a systematic perturbation of time series of temperature to analyze the responses of the *B. tabaci* population dynamics model to temperature change.

The climate models outputs (used to generate climate scenarios) have been verified by the Intergovernmental Panel on Climate Change (IPCC) scientific board (IPCC, 2007) and by researchers from other research institutions and organizations. The results of these verifications showed that the output of climate models provides not a deterministic forecast but only a probabilistic range of values of meteorological driving variables (IPCC, 2007; IPCC-TGICA, 2007).

The verification of climate models for the last 150 years performed by Anagnostopoulos et al. (2010) evidences uncertainties in the annual mean temperatures and their standard deviation. In particular, inter-annual fluctuations in temperature are strongly smoothed in climate models with respect to the observations. The uncertainties on temperature (mean and standard deviation) are low on a global scale, but at continental or lower scale errors are higher (Koutsoyiannis et al., 2008).

The highlighted uncertainties in climate model outputs strongly affects the possibility of producing a reliable scenario regarding future spatial and temporal patterns of temperature for the purpose of analysing the response to temperature change of *B. tabaci* population dynamics. The analysis of the sensitivity to temperature of *B. tabaci* population dynamics performed here is based on a perturbation approach in which the forcing variable (temperature) is perturbed by adding 2 °C to the current climate average. The thermal perturbation is considered over a 20-year timescale.

The temperature perturbation of +2 °C is the outcome of an analysis of the European climate over the last 50 years. In particular, since the second half of 1980s, the Euro-Mediterranean area has been affected by an abrupt climatic change due to a reconfiguration of the Westerlies trajectories. At a macroscale, this phenomenon has been highlighted by the strong positive values of the NAO index (North Atlantic Oscillation) since the second half of the 1980s (Hurrell, 1995; Werner et al., 2000; Scheffinger et al., 2002). Moreover, the historical recurrence of phases with persistent positive NAO values in the last millennium has been also highlighted by means of suitable paleo-climatic proxies (Trouet et al., 2009). This change in circulation caused an abrupt increase of +1 °C in yearly average temperature over the period 1988–2010 relative to the period 1973–1987 (Mariani et al., 2012). At lower space scale (regional) and in spring period, the thermal anomaly rose to 2 °C. On the basis of this evidence, it has been assumed that a similar kind of circulation change might occur in the next 20 years.

Another important point supporting the choice of +2 °C as the temperature perturbation is the consistency of this value with climate projections. The majority of these projections are based on increased concentrations of greenhouse gases in the long term. An increase in temperature in the range 1.4–5.8 °C by the year 2100 has been projected if CO₂ increase remains stable (IPCC, 2007), or 1.5–4.5 °C if atmospheric CO₂ concentration doubles (also known as “equilibrium climate sensitivity”; see IPCC-TGICA, 2007). These projections are based on a very long timespan, and results cannot be interpolated for a period of 20 years.

Support for a +2 °C temperature perturbation comes from short-term climate projections for the European area. For example, the chosen perturbation is consistent with projection provided by the PESETA Project (EC, JRC and IPTS, 2009). This project considers change in thermal and rainfall patterns from 2010 to 2040. Projections have been obtained from the model RCA3/ECHAM5 of the Danish Meteorological Institute (project PRUDENCE: Prediction of Regional scenarios and

Uncertainties for Defining European Climate change risks and Effects (<http://prudence.dmi.dk/>). The PESETA Project estimates that summer temperatures in most southern European regions will increase by 3 °C in the next 30 years whereas most northern European regions can expect an increase of 2 °C.

Based on the above-mentioned historical evidence and the projected European climate scenario, the choice of +2 °C as the temperature perturbation seems to be representative of the possible extreme temperature increase over the next 20 years in Europe. For the purpose of the analysis of the response to temperature change of *B. tabaci* population dynamics, this can be considered the climate worst case scenario.

Hence, starting from this thermal perturbation approach the sensitivity analysis has been carried out.

Sensitivity analysis in physiologically based population dynamics models driven by meteorological variables (see Gilioli and Mariani, 2011) can be carried out by imposing a perturbation on time series of weather data by means of stochastic methods (Holman et al., 2007) or using deterministic methods, modifying the dataset with predefined changing factors (Katz, 2002). The latter approach has been adopted here, and the forcing variable (temperature) is systematically perturbed by adding 2 °C to the current climate average for a temporal horizon of 20 years.

The climatological data input of the model was retrieved from the WORLDCLIM database (University of California at Berkeley) (Hijmans et al., 2005; WorldClim, online). The database contains monthly mean temperature (period 1950–2000) gridded with a spatial resolution of 5 arcminutes (0.0833°—10 km). In the WORLDCLIM database, gridded data were assembled from a large number of sources including (i) The Global Historical Climate Network Dataset (GHCN) version 2 (<http://www.ncdc.noaa.gov/pub/data/ghcn/v2>), (ii) the climatological normals (CLINO) for 1961–1990 (WMO, 1996), and (iii) the FAOCLIM 2.0 global climate database (FAO, 2001). For the simulation of population dynamics in Europe, the original world grid was restricted to the area –11 to 41 °E, 30 to 73 °N).

E.4. VIRUS ESTABLISHMENT

The probability of virus establishment is a random variable (indicated in the following by E) that can assume only two values: 0 (non-establishment), 1 (establishment). In each point of the grid the value of the variables BP and BA is known. It follows that it is possible to calculate the probability of establishment in each point of the grid using the following formula

$$P(E = 1 | BP, BA) = f(BP, BA) \quad (2)$$

where f is an increasing function of $B. tabaci$ population pressure like a logistic-type curve. In particular, f is chosen to be

$$f(BP) = \frac{1.03}{1 + 30 \exp(-0.2x)} - 0.033226.$$

The probability increases with $B. tabaci$ population pressure and $B. tabaci$ availability.

- For $BA = a$, the probability of establishment as function of $B. tabaci$ population abundance has the shape represented in Figure E.2.
- For $BP = p$, the probability of establishment as function of $B. tabaci$ availability has the shape represented in Figure E.3.

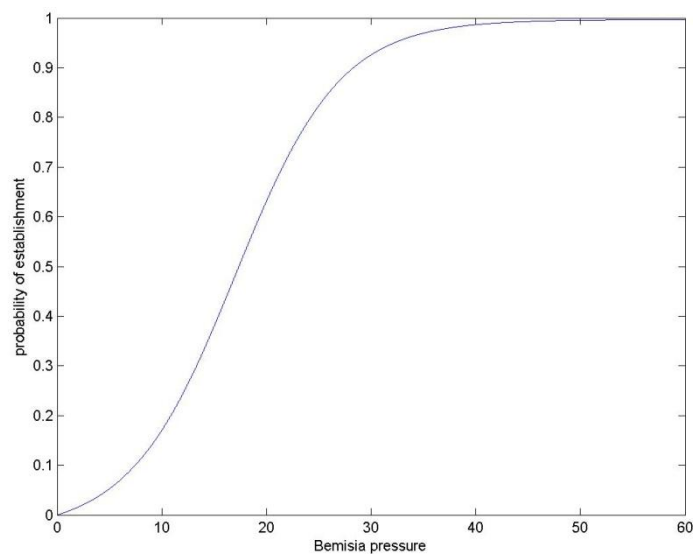


Figure E.2: Probability of establishment as function of *B. tabaci* population abundance

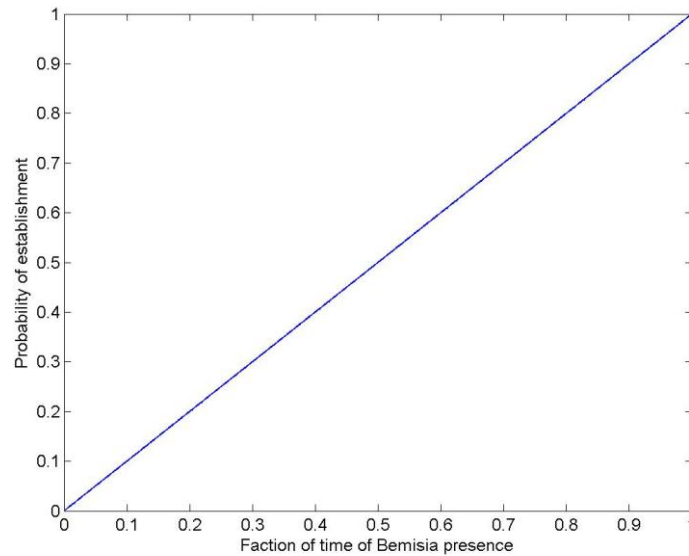


Figure E.3: Probability of establishment as function of *B. tabaci* presence

Maps representing the probability of virus establishment obtained considering the temperature current climatic situation and the climate change scenario + 2 °C are reported in Figures E.4 and E.5.

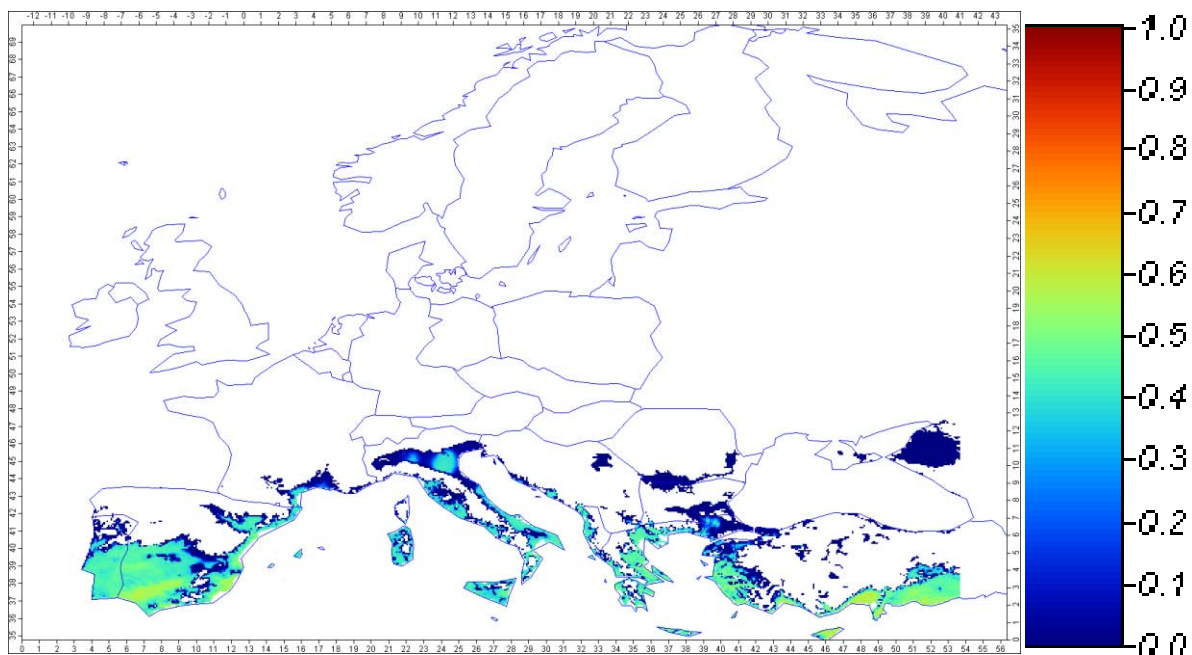


Figure E.4: Distribution of the probability of virus establishment obtained considering the current temperature and climatic situation

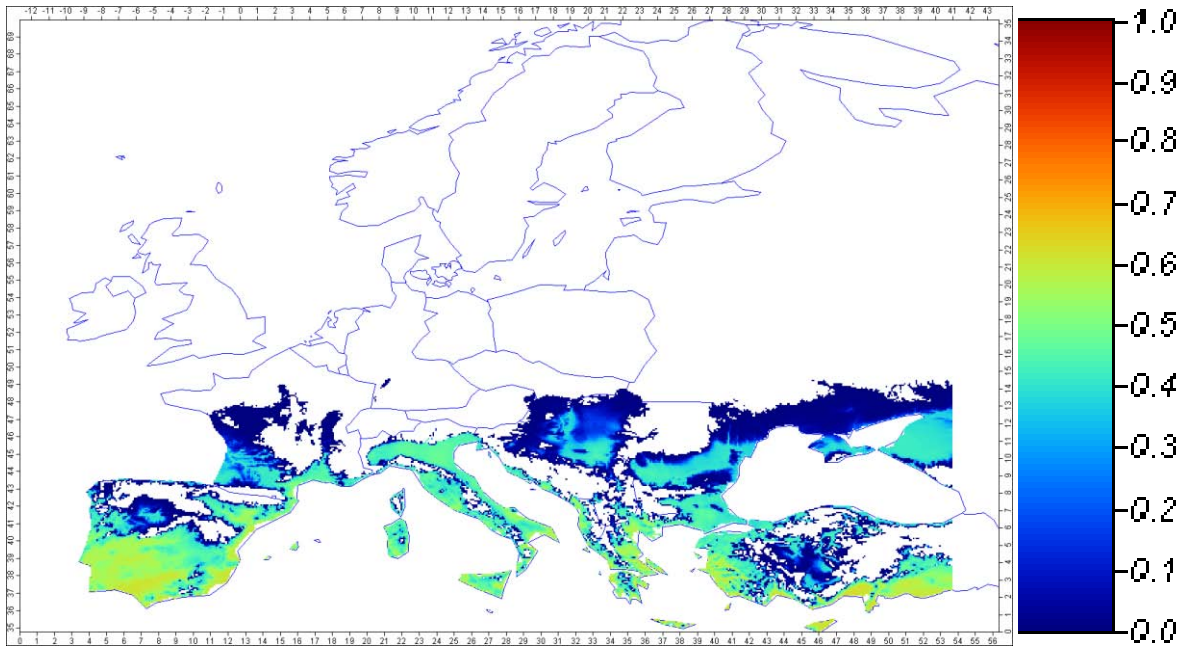


Figure E.5: Distribution of the probability of virus establishment in the climate change scenario + 2 °C.

F. RISK REDUCTION OPTIONS

1. Risk reduction options for *B. tabaci* and the viruses it transmits

1.1. Introduction

In this appendix the Panel summarises the risk reduction options (RROs) for *Bemisia tabaci* and the viruses it transmits. Panel members performed extensive literature searches and contacted researchers to obtain the latest information concerning management options for this pest and the viruses it transmits. More than 1 000 references were retrieved and evaluated. The most important ones are included in this section. The Panel benefited from the EFSA guidance document on methodology for evaluation of the effectiveness of options to reduce the risk of introduction and spread of organisms harmful to plant health in the EU territory (EFSA, 2012) to classify and evaluate the RROs. The Panel used the classification of RROs as presented in the guidance document and summarised the information for each category. In some cases the Panel had to limit the amount of information for certain RROs and decided to present one or more examples about possibilities for use of an option (e.g. for integrated pest management (IPM) methods and for certification systems).

Council Directive 2000/29/EC uses the terms European and non-European populations of *B. tabaci*, although in the PRA a taxonomy-based description is used to describe *B. tabaci* species. For consistency with the directive in the RRO section, the Council terminology is used.

After summarising the RROs for *Bemisia* and its viruses, the Panel made an EXCEL file listing all options and rated the effect of each option, uncertainty, its applicability and feasibility (see Table F.1).

1.2. Overview of risk reduction options for *B. tabaci* and the viruses it transmits, including current phytosanitary measures

The Panel used the classification of RROs as presented in the EFSA guidance document on methodology for evaluation of the effectiveness of options to reduce the risk of introduction and spread of organisms harmful to plant health in the EU territory (EFSA, 2012):

1. Options for consignments – prohibition.
2. Options for consignments – pest freedom: inspection or testing.
3. Options for consignments – prohibition of parts of the host or of specific genotypes of the host.
4. Options for consignments – pre-entry or post-entry quarantine system.
5. Options for consignments – phytosanitary certificates and other compliance measures.
6. Options for consignments – preparation of the consignment.
7. Options for consignments – specified treatment of the consignment/reducing pest prevalence in the consignment.
8. Options for consignments – restriction on end use, distribution and periods of entry.
9. Options preventing or reducing infestation in the crop – treatment of the crop, field, or place of production in order to reduce pest prevalence.
10. Options preventing or reducing infestation in the crop – resistant or less susceptible varieties.
11. Options preventing or reducing infestation in the crop – growing plants under exclusion conditions (glasshouse, screen, isolation).
12. Options preventing or reducing infestation in the commodity – harvesting of plants at a certain stage of maturity or during a specified time of year.

13. Options preventing or reducing infestation in the crop – certification scheme.
14. Options ensuring that the area, place or site of production, remains free from the pest – maintaining Pest Free Area (PFA).
15. Options ensuring that the area, place or site of production or crop is free from the pest – pest free production site.
16. Options ensuring that the area, place or site of production or crop is free from the pest – inspections, surveillance.
17. Options for other types of pathways – natural spread, spread by human activities (people movement, transports, machineries, trade), vectors, phoresy.
18. Other relevant information.

1.2.1. RRO Category 1. Options for consignments – prohibition of the consignment

This RRO concerns both *B. tabaci* and the viruses it transmits, and is valid for import into the PRA area from all third countries. Theoretically, prohibition of host plant commodities is very effective in reducing the risk of entry of both *B. tabaci* and the viruses it transmits, but applicability is limited by the large host plant range of the pest and its viruses.

Current situation in the EU

Currently the introduction into the EU of plants, plant products and other objects, specified by Council Directive 2000/29/EG Annex III Part A, is prohibited. Some of these commodities are host plants of *B. tabaci* and the viruses it transmits: *Quercus* spp., *Crataegus* spp., *Prunus* spp., *Pyrus* spp., *Rosa* spp., *Solanum* spp., *Vitis* spp., *Citrus* spp., *Poncirus* spp. and *Fragaria* spp. These genera cover 27 hosts in the range of the pest, but the majority of host plants are not included in the Annex.

1.2.2. RRO Category 2. Options for consignments – pest freedom: inspection or testing

This RRO concerns both *B. tabaci* and the viruses it transmits, and is valid for import in the PRA area from all third countries. Inspection of consignments is performed prior to export and at the point of entry to the PRA area, or at other points determined by National Plant Protection Organisations (NPPOs).

The International Standard for Phytosanitary Measures (ISPM) No 31 (FAO, 2009a) provides guidance on appropriate sampling methodologies for inspection or testing of consignments/lots. These include parameters such as acceptance level, level of detection, confidence level, efficacy of detection and sample size. The acceptance number for a particular pest designates how many individual pest organisms are permitted in a sample of a given size before phytosanitary action is taken. Since *B. tabaci* and the viruses it transmits are included in Part A of Annex I of Council Directive 2000/29/EC, the acceptance number for these quarantine organisms is zero. The level of detection corresponds to the minimum level of infestation that the sampling method will detect. However, ISPM No 31 (FAO, 2009a) does not provide reference values for this parameter. The confidence level indicates the probability that a consignment with a degree of infestation exceeding the level of detection will be detected. The commonly used value is 95 %; therefore, the remaining 5 % of all consignments infested with *B. tabaci* or infected with the viruses it transmits to a degree above the level of detection will pass the pre-export check at the country of origin. The EU legislation and the ISPMs of the International Plant Protection Convention (IPPC) do not require a minimum confidence level as regards inspection of consignments. The efficacy of detection is the probability that an inspection or test of an infested unit will detect a pest organism. As efficacy depends on the ease of visual detection and/or manifestation of symptoms, it could never in practice reach 100 % for *B. tabaci*-transmitted viruses, because of the possibility of latent infections. The determination of an appropriate sample size involves the four values (i.e. acceptance level, level of detection, confidence level and efficacy of detection) described above and the size of the inspected lot or consignment. However, demanding a large sample size may lead to operational difficulties and practical feasibility is often considered when determining the intensity of inspection. Thus, NPPOs of exporting countries

may set minimum and maximum values for sample size, which are not currently regulated by the EU/IPPC.

ISPM No 23 (FAO, 2005) describes the general and specific requirements for the inspection of consignments of plants, plant products and other regulated articles at import and export. Compliance with phytosanitary requirements is determined through visual examination, documentary checks and identity and integrity checks. As regards visual examination, ISPM No 27 (FAO, 2006) provides guidance on the structure and content of the IPPC protocols for regulated pests. Such a protocol has been developed by the European and Mediterranean Plant Protection Organization (EPPO) for *B. tabaci*, covering detection and morphological identification (EPPO, 2004). However, during visual inspection of the plants, eggs and young instars of *B. tabaci* may remain undetected because of their small size and transparent colour. Adults present at low densities may also remain undetected. Further, misidentification as related species, such as *Trialeurodes vaporariorum*, can decrease the effectivity of inspection. Therefore, inspection as a phytosanitary measure for detection of *B. tabaci* is not fully reliable.

Inspection allows detection of symptomatic infections of host plants with *B. tabaci*-transmitted viruses. However, many of these viruses may cause asymptomatic infections and therefore remain undetected. Begomovirus species identification can be performed by molecular methods only. *B. tabaci* also transmits a number of viruses assigned to four other genera: the Criniviruses, Ipomoviruses, Carlaviruses and Torradoviruses (Wisler et al., 1998). Directive 2000/29/EC lists only seven out of the 200 different viruses transmitted, while aiming to cover all *B. tabaci*-transmitted viruses. This renders inspection useless in cases of infection with unknown virus species, although their regulation is attempted.

Although the current regulations require official inspection, the methods to confirm absence or establish presence of the pest are not clearly specified. In most cases, it is a responsibility of the NPPOs to decide on the sampling procedures and the frequency of inspections. Thus, even if a particular set of inspection procedures is considered adequate by an NPPO, it may not be sufficient to detect *B. tabaci* and/or its viruses, especially when dealing with large volumes/crop areas and low population densities.

Current situation in the EU

Section I in Part A of Annex IV of Council Directive 2000/29/EC specifies the requirements for introduction and movement of plants, plant products and other objects originating outside the community into and within all Member States. Inspection for harmful organisms at appropriate times and prior to export is required for the following plants for planting: trees and shrubs (item 39), annual and biennial plants other than *Gramineae* (item 41) and herbaceous perennial plants for planting of the families *Caryophyllaceae*, *Compositae*, *Cruciferae*, *Leguminosae* and *Rosaceae* (item 44). Furthermore, naturally or artificially dwarfed plants for planting (item 43) should be officially inspected for harmful organisms at least six times a year for the required minimum of two years of growing in registered nurseries prior to dispatch. Plants of herbaceous species, *Ficus* spp. and *Hibiscus* spp. intended for planting (item 45.1) should be subjected to weekly official inspections during nine weeks prior to export. For cut flowers of *Aster* spp., *Eryngium*, *Gypsophila*, *Hypericum*, *Lisianthus*, *Rosa*, *Solidago*, *Trachelium* and leafy vegetables of *Ocimum* (item 45.2), the Directive requires official inspection prior to export, unless the consignments originate in a country free from *B. tabaci*. Part B of Annex IV lists the requirement for introduction and movement of consignments into protected zones within the Community. In the case of *B. tabaci*, these are Ireland, UK, Sweden, Finland and parts of Portugal. For plants for planting of the genera *Begonia*, *Ficus* and *Hibiscus* (item 24.3), and *Euphorbia pulcherrima* (item 24.2), which do not originate from an area free of *B. tabaci*, the Directive requires inspection throughout the whole production period. If *B. tabaci* is found at the place of production, then weekly official inspections should be carried out, with the last one taking place prior to export.

There are no specific requirements with respect to *B. tabaci* for the procedures for inspection of consignments of plants for planting. There are also no specific requirements with respect to viruses transmitted by *B. tabaci* for inspection of consignments.

1.2.3. RRO Category 3. Options for consignments - prohibition of parts of the host or of specific genotypes of the host

This RRO concerns both *B. tabaci* and the viruses it transmits, and is valid for import in the PRA area from all third countries.

All life stages of *B. tabaci* are usually found on the underside of the leaves (Bedford et al., 1994). The most resistant stage, which has greatest chance of surviving transportation and storage, is the pharate adult. Thus, removal of flowers and fruits will have no effect if the pest is present on the planting material. Many viruses transmitted by *B. tabaci* (especially begomoviruses) cause systemic infections of the plant host (Saeed et al., 2005; Kon et al., 2009) and therefore prohibition of specific parts of the host would not reduce the risk of virus entry.

Unless leaves are prohibited, this measure would have no effect in reducing the risk of entry of *B. tabaci*. However, such a measure would be unfeasible for planting material. Regarding tomato fruit, *B. tabaci* can be carried on remaining green parts such as leaves (tomatoes on the vine) and, in the case of very high population density at the place of production, on sepals and peduncles. If the commodity originates from countries where TYLCV is present, there is a risk of entry of viruliferous *B. tabaci* in the PRA area. A requirement for removal of green parts attached to fruit would effectively minimise the risk of entry of *B. tabaci*. For viruses causing systemic infections, which constitute the majority of *B. tabaci*-transmitted viruses, prohibition of parts or specific genotypes of the host will have no effect in reducing the risk of entry.

Current situation in the EU

Trees and shrubs (item 39), annual and biennial plants other than *Gramineae* (item 41) and herbaceous perennial plants for planting of the families *Caryophyllaceae*, *Compositae*, *Cruciferae*, *Leguminosae* and *Rosaceae* (item 44) should be free from flowers and fruits. (NB: if cleaning of flowers and fruits is regarded as preparation of consignment, overlap occurs with RRO 6).

1.2.4. RRO Category 4. Options for consignments – pre-entry or post-entry quarantine system

This RRO concerns both *B. tabaci* and the viruses it transmits, and is valid for import in the PRA area from all third countries.

In general, pre- and post-entry quarantine systems can be very effective in checking for the presence of harmful organisms. The current EU regulation of a nine-week pre-entry monitoring period for herbaceous hosts found infested with *B. tabaci* is not a true pre-entry quarantine system, because this would require a closed environment. However, this monitoring period is sufficient to ascertain whether the pest has been eliminated from the place of production, as *B. tabaci* can complete two or three generations during these nine weeks. EU Member States may impose a post-entry quarantine in the case of a substantiated suspicion that particular consignments may harbour harmful organisms. This allows detailed inspection and testing of the suspicious planting material and possible development of symptoms in the case of asymptomatic viral infections. However, virus expression requires a long period, and testing for viruses, in combination with the large number of consignments that have to be placed in these closed quarantine systems, renders quarantine unfeasible.

Current situation in the EU

The current regulations do not require pre-entry quarantine for hosts of *B. tabaci* and the viruses it transmits. Nevertheless, in some cases, there are requirements for compulsory growing periods prior to export, e.g. two years of growing in registered nurseries for naturally or artificially dwarfed plants for planting prior to export. If *B. tabaci* has been found on plants for planting of herbaceous species, *Ficus* spp. and *Hibiscus* spp. intended for export in the PRA area, the Directive requires appropriate

treatment to ensure pest freedom and official inspections weekly during the nine weeks prior to export. The obligation of a post-entry quarantine period is considered as a possible protective measure in Article 13c of Directive 2000/29/EC.

1.2.5. RRO Category 5. Options for consignments – Phytosanitary certificates and other compliance measures

This RRO concerns both *B. tabaci* and the viruses it transmits, and is valid for import in the PRA area from all third countries.

Phytosanitary certificates represent official declarations on behalf of the country of origin that exported consignments do not harbour harmful organisms. However, ensuring the pest freedom of the consignments requires reliable inspection/testing and, in case of established infestation, appropriate measures to eliminate the pest. Demanding guarantees of pest freedom from the exporting country is a very efficient measure against the entry of *B. tabaci* and the viruses it transmits, provided that the chosen methods for inspection and treatment are fully effective. Tomato fruit, which are associated with risk of entry of TYLCV, are not regulated by the directive. However, tomato fruit with green parts such as sepals, peduncles and leaves (tomatoes on the vine) can also carry *B. tabaci*, thus facilitating transfer of the virus to other hosts (Delatte et al., 2003). If a phytosanitary certificate is required for this commodity, the risk of entry of TYLCV and *B. tabaci* associated with it would significantly decrease.

Current situation in the EU

Council Directive 2000/29/EC requires the issuing of phytosanitary certificates in the country of origin for all plants and plant products listed in Annex V, Part B, of the Directive (covering the special requirements for the introduction and movement of plants, plant products and other objects originating outside the Community). The phytosanitary certificates are issued in accordance with the IPCC, ISPM 7 (FAO, 2011a), Export certification system and ISPM 12 (FAO, 2011b), Guidelines for phytosanitary certificates. They certify that the regulated articles which are subject to import in the EU have undergone inspection/testing in accordance with the official procedures and that they are free from quarantine pests and conform to the current phytosanitary requirements. Other specific requirements, such as derogations and agreements, may also be imposed by the agreement of the contracting parties implementing the trade.

Also, as stipulated in Article 13a(4) of the Directive, the phytosanitary certificate should include an additional declaration stating which special requirements listed under the relevant position in Annex IV have been fulfilled, when options are listed.

The regulated articles listed in Annex IV, Section I, which may harbour *B. tabaci* and/or viruses it transmits are the following:

- item 39: Trees and shrubs for planting;
- item 41: Annual and biennial plants other than *Gramineae*, for planting;
- item 44: Herbaceous perennial plants for planting of families *Caryophyllaceae*, *Compositae*, *Cruciferae*, *Leguminosae* and *Rosaceae*;
- item 40: Deciduous trees and shrubs for planting;
- item 43: Naturally or artificially dwarfed plants for planting;
- item 45.1: Herbaceous species and species of the genera *Ficus* and *Hibiscus* for planting;
- item 45.2: Cut flowers of *Aster* spp., *Eryngium*, *Gypsophila*, *Hypericum*, *Lisianthus*, *Rosa*, *Solidago*, *Trachelium*, leafy vegetables of *Ocimum*;
- item 45.3: *Solanum lycopersicum* for planting originating from countries where TYLCV is known to occur;
- item 46: Plants for planting from countries where viruses transmitted by *B. tabaci* occur.

1.2.6. RRO Category 6. Options for consignments – preparation of the consignment

This RRO concerns both *B. tabaci* and the viruses it transmits, and is valid for import in the PRA area from all third countries.

Cleaning of plants with water and removal of older leaves will have a minor effect on the vector, *B. tabaci*, by reducing its abundance to some extent, but will not have any effect on established virus diseases.

Current situation in the EU

Annex IV, Part A, Section I, of Council Directive 2000/29/EC requires cleaning of trees and shrubs (item 39), annual and biennial plants other than *Gramineae* (item 41) and herbaceous perennial plants for planting of families *Caryophyllaceae*, *Compositae*, *Cruciferae*, *Leguminosae* and *Rosaceae* (item 44) from flowers and fruits. More complex preparations are required for artificially dwarfed plants for planting (item 43), including cleaning, planting on treated media and packing in closed containers with registration plates not specifically targeted at *B. tabaci* or the viruses it transmits.

1.2.7. RRO Category 7. Options for consignments – specified treatment of the consignment/ Reducing pest prevalence in the consignment

This RRO concerns both *B. tabaci* and the viruses it transmits, and is valid for import in the PRA area from all third countries.

Treatment of consignments resulting in elimination of *B. tabaci* is often not realistic as it interferes with product quality. Furthermore, there is no treatment method available in case of infection with *B. tabaci*-transmitted viruses.

Current situation in the EU

Current legislation does not require use of this option, as all commodities should be free of the pest prior to export (i.e. before packing). Therefore, treatment of consignments is not relevant for *B. tabaci* and the viruses it transmits.

1.2.8. RRO Category 8. Options for consignments – restriction on end use, distribution and periods of entry

This RRO concerns both *B. tabaci* and the viruses it transmits, and is valid for import in the PRA area from all third countries.

Any restrictions on the periods of entry of consignments will have no effect on the risk of entry of *B. tabaci*, as it may develop in greenhouses all year long as well as outdoors in large parts of the southern Mediterranean area. However, the end use of the commodities is important in order to identify the level of risk of establishment associated with the relevant pathway. For example, planting material poses a higher risk than products intended for consumption or processing (fresh fruit and vegetables).

Current situation in the EU

No RROs are listed in the Directive concerning this category.

1.2.9. RRO Category 9. Options preventing or reducing infestation in the crop – treatment of the crop, field, or place of production in order to reduce pest prevalence

The Panel identified following RROs in this category:

Cultural methods

- Crop free periods
- Planting date
- Sanitation period before planting

- Plant manipulation before planting
- Pruning
- Roguing / Virus Infected Plant removal
- Weed management
- High planting density
- Barriers
- Intercropping
- Mulching
- Fertilization
- Irrigation
- Overhead irrigation
- Sanitation / Crop residue disposal
- Scouting

Biological control

- Parasitoids
- Predators
- Entomopathogens

Chemical control

- Acetylcholinesterase (AChE) inhibitors: Carbamates and Organophosphates
- Sodium channel modulators: Pyrethrins, Pyrethroids
- Nicotinic acetylcholine receptor (nAChR) agonists: Neonicotinoids
- Nicotinic acetylcholine receptor (nAChR) agonists: Sulfoxaflor
- Juvenile hormone mimics: Pyriproxifen
- Selective homopteran feeding blockers: Pymetrozine
- Inhibitors of chitin biosynthesis, type 1: Buprofezin
- Mitochondrial complex I electron transport inhibitors: METI acaricides and insecticides
- Inhibitors of lipid synthesis: Tetriconic and Tetricamic acid
- Ryanodine receptor modulators: Diamides
- Azadirachtin
- Oils
- Soaps

Integrated Pest Management

1.2.9.1. Cultural methods:

Crop free periods

This RRO concerns both *B. tabaci* and the viruses it transmits. A mandatory crop-free period can be very effective in eliminating viruses (Polston and Lapidot, 2007). Crop-free periods can also reduce mass migrations of insects directly from one crop to another (Hilje et al., 2001). Examples of effective use of crop-free periods are a two-month period in the Arava region in Israel (Ucko et al., 1998) and in Florida (Schuster et al, 2011) and a mandatory three-month period in the Dominican Republic (Polston and Anderson, 1997). For more examples see Hilje et al. (2001).

Planting date

This RRO concerns both *B. tabaci* and the viruses it transmits. Some amount of vector and virus inoculum can often be avoided by planting early or late. Examples are presented in Polston and Lapidot (2007) and Hilje et al. (2001).

Sanitation period before planting

This RRO concerns both *B. tabaci* and the viruses it transmits. To prevent infection of a new crop with a resident whitefly population, CARM (2011) recommends maintaining greenhouses totally free of

crop residues and weeds for at least six weeks before planting. This period can be reduced to four weeks if temperatures inside greenhouses reach 60 °C. Weeds and crop residues in the close vicinity of the greenhouse should also be removed.

Plant manipulation before planting

This RRO concerns both *B. tabaci* and the viruses it transmits. CARM (2011) advises transporting plants from the nursery directly to the greenhouse in “closed” vehicles without passing other cultivations, warehouses or locations with *B. tabaci* infestations.

Pruning

This option concerns only *B. tabaci*. It is recommended that leaves be removed from the lower part of the plant to reduce *B. tabaci* emergence in crops where this is possible (e.g. tomato) (CARM, 2011). Furthermore, all culled tomatoes must be disposed of as far from production fields as possible (Schuster et al., 2011).

Roguing / virus-infected plant removal

This RRO mainly concerns the viruses. Minimising or eliminating virus inoculum sources is effective in reducing virus problems. For example, growers in Spain and Florida rogue infected plants in the field early (at least until second tie) in the season by pulling them out and by putting them in plastic bags, which are then sealed and disposed of as far from production fields as possible (CARM, 2010; Schuster et al., 2011). Roguing young infected plants appears to reduce the amount of secondary spread within a field when infection is low at the start of the season. Roguing of young infected plants is not successful at high rates of infection, i.e. higher than 10 %. This method is also impractical when plants have been in the field for more than six weeks in the case of TYLCV (Polston and Lapidot, 2007), but it can be recommended for TSWV during the whole cropping season (CARM, 2010). If vectors are present in the crop, roguing is recommended after an effective chemical treatment against vectors (CARM, 2010).

Weed management

This RRO concerns both *B. tabaci* and the viruses it transmits. Some authors advise removing all weeds in the greenhouse and open field, as they can harbour whitefly populations as well as viruses (Polston and Lapidot, 2007; Hilje et al., 2001). However, there are weeds which can act as important reservoirs of natural predators, parasitoids and entomophagous fungi that can be very effective in reducing whitefly populations (CARM, 2011). Thus, selective weed management may offer the best solution (Schuster et al., 2011).

High planting density

This RRO concerns both *B. tabaci* and the viruses it transmits. The concept of increasing the density of crop plants per unit area to decrease disease incidence is based on the principle that, given a fixed number of vectors, the more crop plants there are per unit area, the smaller the proportion of plants those insects can infect (Broadbent, 1969). Thus, a greater number of plants escape infection and infestation, and potentially produce a higher total yield per unit (Hilje et al., 2001). Positive results have been obtained in cassava, where high planting density reduced infection by the African cassava mosaic virus (ACMV) (Ahohuendo and Sarkar, 1995). However, other results are contradictory, as in the case of higher silverleaf symptom severity in zucchini squash at high plant density (Powell et al., 1993; Hooks et al., 1998).

Barriers

This RRO concerns both *B. tabaci* and the viruses it transmits. Gerling and Horowitz (1984) suggested that the majority of *B. tabaci* adults normally fly lower than 2 m above ground level. Therefore, the placement of a tall physical barrier (i.e. screening, polyethylene plastic or wood) around a crop field may impede or delay whitefly movement into the crop (Hilje et al., 2001). Another possibility is the use of relatively tall graminaceous species such as sorghum (*Sorghum bicolor*), Johnson grass (*Sorghum halepense*), corn (*Zea mays*) or elephant grass (*Pennisetum purpureum*). However, some individuals are able to fly higher and cross the physical barrier (Isaacs and Byrne, 1998). According to

Hilje et al. (2001) this may partly explain the inconsistent effects of barriers on whitefly and virus incidence in the crop. Example of a positive result with barriers: is provided by Gravena et al. (1984), who were able to reduce *B. tabaci* adult densities and increase densities of its predators by planting sorghum barriers around tomato fields in Brazil. In contrast, Cohen et al. (1988) found more whiteflies and a higher incidence of TYLCV in plots protected by 1.5-m-tall black polyethylene barriers than in plots without barriers.

Intercropping

This RRO concerns both *B. tabaci* and the viruses it transmits. Intercropping refers to spatial arrays of crops including two or more plant species in close proximity to each other, within a given plot. According to Hilje et al. (2001), crop associations may create a refuge for natural enemies and/or manipulate the host-seeking behaviour of the pest and result in lower infestation of the principal or most susceptible crop. These authors stated that a good trap crop to manage whiteflies is one that is very attractive to whiteflies, retains populations for the life of the crop, is not a host of any whitefly transmitted viruses, and is a poor reproductive host for whiteflies. Examples are given in their review. Unfortunately, such crops are difficult to find. Even if adequate plant species for intercrops were available, the logistics of managing two crops simultaneously can be difficult in a commercial setting. Until now, this approach has not proven to be reliable to deal with whiteflies and whitefly transmitted viruses.

Mulching

This RRO concerns both *B. tabaci* and the viruses it transmits. The objective for using mulches to manage whiteflies is to reduce the insect's ability to find the crop (Hilje et al., 2001). The mode of action of inert ground covers such as plastics, sawdust, straw and rice husk mulches has been attributed to interference with visual host-finding or suicidal attraction to the sun-heated mulch (Cohen, 1982; Cohen and Berlinger, 1986). Examples are reviewed by Hilje et al. (2001). Recently, Schuster et al. (2011) recommend using ultraviolet light reflective (aluminium) mulch on those plantings commonly infested with whiteflies and infected with TYLC.

Fertilisation

This RRO concerns *B. tabaci*. Hilje et al. (2001) concluded that there may be some potential to manipulate whitefly populations through fertilisation practices, particularly of available nitrogen. Bentz et al. (1995) found more *B. tabaci* (biotype B) on fertilised poinsettia plants than on unfertilised plants in greenhouse choice tests. Some other examples illustrating the effect of fertilisation are given by Hilje et al. (2001).

Irrigation

This RRO concerns *B. tabaci*. Mor (1987) reported that avoiding water-stressed cotton could help reduce whitefly infestations. This idea has been supported by other authors, such as Flint et al. (1994, 1995, 1996), who found that increasing the irrigation frequency of cotton plants reduced water stress and decreased numbers of whiteflies.

Overhead irrigation

This RRO concerns *B. tabaci*. Castle et al. (1996) found significant reductions in numbers of whitefly eggs and nymphs in sprinkler irrigated cotton and cantaloupe crops compared with furrow irrigation, and suggested that this may be due to a disruptive effect of water on adult whiteflies. The effects of overhead irrigation are corroborated by observations that rain and blowing dust can contribute to substantial mortality by dislodging eggs and nymphs of *B. tabaci* from cotton leaves (Naranjo, 2001).

Sanitation / crop residue disposal

This RRO concerns *B. tabaci* and the viruses it transmits. Old tomato plants are one of the best-known reservoirs of viruliferous whitefly (Hilje et al., 2001). Old tomato plant can support *B. tabaci* reproduction and virus replication, but old plants are not ideal hosts for whiteflies and, thus, whiteflies emerging on these plants are likely to leave in search of better-quality hosts. The removal and destruction of tomato plants immediately after harvest (within five days of final harvest) reduces

whitefly populations in the area and helps to reduce the transmission of virus to nearby plantings (Polston and Lapidot, 2007; Schuster et al., 2011). Volunteer tomato plants in and around fields and greenhouses should be removed as they can serve as reservoirs. To decrease whitefly numbers and sources of plant begomovirus such as TYLCV, Schuster et al. (2011) recommend the use of a contact desiccant (“burn down”) herbicide in conjunction with a heavy application of oil at a concentration of 3 % or higher and an adjuvant.

Scouting

This RRO concerns *B. tabaci* and the viruses it transmits. Particularly in open-field production, scouts can be used very effectively to minimise incidence of virus-infected plants (Polston and Lapidot, 2007) by monitoring whitefly populations weekly or biweekly for adults and whitefly nymphal stages on tomato plants. Sampling results are used for determining the optimal time for applying insecticides or other control measures. Scouting of *B. tabaci* is normally conducted by counting adults on plants or on yellow sticky traps (Arnó et al., 2009). Countings are performed weekly when pest risk is high and fortnightly when pest impact is presumably less important. Examples of sampling methods performed in some European areas where *B. tabaci* is present are presented in Arnó et al. (2009).

1.2.9.2. Biological control

This RRO concerns *B. tabaci* and the viruses it transmits. All developmental stages of *B. tabaci* can be attacked by natural enemies. A great diversity of parasitoids (73 species), predators (164 species) and entomopathogens (mainly fungi; 11 species) are able to reproduce and/or prey on *B. tabaci* (see Faria and Wraight, 2001; Gerling et al., 2001; Arnó et al., 2010b) for a thorough review):

- The most common *parasitoids* of *B. tabaci* are Hymenoptera of the family Aphelinidae and particularly from the genera *Encarsia* and *Eretmocerus*. *Encarsia* species endoparasitise *B. tabaci*. In contrast, *Eretmocerus* species oviposit externally under the nymphal host, and, upon eclosion, the first instar larva penetrates the host cuticle, feeds and pupates internally. Additional mortality is inflicted by the adult female parasitoids on *B. tabaci* through host feeding that occurs preferably on young instars of *B. tabaci*.
- The most important *predators* of *B. tabaci* are Coccinellidae, Miridae and Anthocoridae (Hemiptera), Chrysopidae (Neuroptera) and predatory mites (Acari: Phytoseiidae). Most predators of *B. tabaci* are polyphagous species and, depending on the natural enemy, they are able to prey upon all nymphal instars (e.g. Chrysopidae) or are specialised on a certain stage/instar (e.g. predatory mites on eggs).
- *Bemisia tabaci* is also susceptible to attack by *entomopathogenic* organisms such as fungi, which penetrate the body of *B. tabaci* after germination of their spores. The development of their mycelia destroys *B. tabaci* tissues and organs. When *B. tabaci* dies, the mycelia come out, cover the insect body and form spores, contributing to fungus spread.

Natural enemies for controlling and managing *B. tabaci* can be used in four different ways:

- 1) *Classical biological control*: introducing natural enemies to a new region where they did not occur before with the aim of long-term *B. tabaci* control;
- 2) *Inoculative biological control*: releasing small numbers of natural enemies early in the crop with the expectation that they will multiply in the crop and that their progeny will control *B. tabaci* for an extended period of time;
- 3) *Inundative biological control*: releasing high quantities of natural enemies to control *B. tabaci* by the released natural enemies themselves;
- 4) *Conservation biological control*: habitat manipulation to protect and enhance populations of natural enemies, thereby reducing *B. tabaci* populations.

Overview of types of natural enemies used for control of *Bemisia tabaci* (parasitoid, predator and pathogens; within each subgroup, natural enemies are listed in alphabetical order).

Parasitoids

Encarsia lutea (Masi) (Hymenoptera: Aphelinidae) is a cosmopolitan parasitoid which has been observed occasionally parasitising *B. tabaci* in different crops (Fernández Fernández et al., 1994).

Encarsia pergandiella Howard (Hymenoptera: Aphelinidae) is an exotic heteronomous hyperparasitoid originating from the Americas (Jacas et al., 2006). It was released in Italy against *Trialeurodes vaporariorum* Westwood (Hemiptera: Aleyrodidae) (Viggiani, 1994), after which it naturally spread along the Mediterranean Basin, parasitising both *T. vaporariorum* and *B. tabaci*. However, owing to its heteronomous hyperparasitic behaviour, it has become a serious nuisance for biocontrol of greenhouse whiteflies in north-eastern Spain (Gabarra et al., 1999).

Eretmocerus eremicus Rose and Zolnerowich (Hymenoptera: Aphelinidae) is a North American parasitoid mass reared commercially on greenhouse whitefly, *T. vaporariorum*, but also able to parasitise *B. tabaci* (Greenberg et al., 2002). This parasitoid was widely used for control of *B. tabaci* until the commercial availability of *E. mundus* (Hoddle et al., 1998; Stansly et al., 2004b, 2005a). Currently its use is recommended only when *T. vaporariorum* coexists in the crop with *B. tabaci* (Stansly et al., 2005a).

Eretmocerus mundus Mercet (Hymenoptera: Aphelinidae) is native to the Mediterranean region, where it is often observed to spontaneously enter greenhouses and parasitise *B. tabaci* in different crops (Urbaneja and Stansly, 2004). It is a biparental species which, like all *Eretmocerus* spp., undergoes an ecto- and endoparasitic stage in its life cycle on the whitefly host (Urbaneja et al., 2007). *Eretmocerus mundus* has been widely used for controlling *B. tabaci* in greenhouses (Urbaneja et al., 2002; Stansly et al., 2004a, b, 2005a, b; Calvo et al., 2009a; Arnó et al., 2010b; Stansly and Natwick, 2010) because it is more effective than *E. eremicus* (Stansly et al., 2005a). Therefore, *E. mundus* has until recently been the basis of biocontrol of *B. tabaci* in protected crops in the Mediterranean (Castañé et al., 2008). However, inoculative releases of parasitoids often require supplementary pesticide treatments, such as insect growth regulators (IGRs), oils, and soaps (Stansly et al., 2004b; Calvo et al., 2009a). Since predators became available, the use of parasitoids such as *E. mundus* in IPM programmes has diminished, but has not totally disappeared.

Predators

Amblyseius swirskii Athias-Henriot (Acari: Phytoseiidae) is a polyphagous predatory mite which preys mainly on *B. tabaci* eggs and crawlers, and rarely on later immature stages (Nomikou et al., 2001). This predatory mite is an effective biological control agent of *B. tabaci* in crops such as sweet pepper and cucumber in many countries (Calvo et al., 2008, 2009a, 2011). However, this predatory mite is not able to establish itself in tomato crops (Koppert and WUR, 2012). *Amblyseius swirskii* is commercially available and it is released mainly by means of hanging up slow-release bags which are evenly distributed in the crop (Calvo et al., 2011). Owing to its polyphagous behaviour, *A. swirskii* is able to control simultaneously infestations of several pests such as *B. tabaci* and *Frankliniella occidentalis* Pergande (Thysanoptera: Thripidae) (Messelink et al., 2008). Because of the success of inoculative releases of this predatory mite, it is now the basis for biological control of *B. tabaci* on large areas of protected crops such as sweet pepper and cucumber (Castañé et al., 2008).

Coenosia attenuata Stein (Diptera: Muscidae) is a Palearctic muscid fly (Pohl et al., 2012). Adults of *C. attenuata*, which have the appearance of a small house fly, are efficient predators of *T. vaporariorum* and *B. tabaci* adults (Tellez et al., 2009). It is common to find large populations of this predator, which spontaneously enters greenhouses, in horticultural and ornamental crops not subjected to broad-spectrum insecticide treatments (Castañé et al., 2008; Tellez et al., 2009).

Delphastus catalinae Horn) and *Clistotethus arcuatus* (Rossi) (Coleoptera: Coccinellidae) have been reported as spontaneously occurring predators of several species of whiteflies, including *B. tabaci*, but usually they are not found in high numbers (Castañé et al., 2008).

Diciphys tamaninii Wagner (Hemiptera: Miridae) is a zoophytophagous predatory bug endemic to the Mediterranean region (Alomar et al., 2002). This predator can help in the biological control of *B. tabaci* and spontaneously colonises tomato crops (Agustí and Gabarra, 2009). However, *D. tamaninii* may also blemish tomato fruits when prey is scarce (Gabarra et al., 1988).

Macrolophus pygmaeus (Rambur) is an endemic zoophytophagous predatory bug which shows some preference for whiteflies (Barnadas et al., 1998). In addition, it is also able to prey on aphids (Alvarado et al., 1997; Lykouressis et al., 2007), thrips (Riudavets and Castane, 1998), leafminers (Arnó et al., 2003) and several lepidopteran pests (Sacco et al., 2007). *Macrolophus pygmaeus* was, until recently, misidentified as *M. melanotoma* (Costa) (= *M. caliginosus* Wagner) and it is still labelled as *M. caliginosus* by the producers of natural enemies (Perdikis et al., 2003; Martinez-Cascales et al., 2006). *Macrolophus pygmaeus* has been used as inoculative and inundative releases for biological control of *B. tabaci* in vegetable greenhouses (Arnó et al., 2010b). Furthermore, it can also be released in seedling nurseries to realise early establishment and improve its distribution over the plants (Lenfant et al., 2000). Under warm conditions, *B. tabaci* populations may escape control by *M. pygmaeus*, and in this situation the combined release of parasitoids and predators is recommended (Gabarra et al., 2006).

Nesidiocoris tenuis Reuter (Hemiptera: Miridae) is a zoophytophagous predatory bug endemic to the Mediterranean basin. This predator commonly appears and colonises in large numbers crops both fields and greenhouses where no broad-spectrum insecticides are used, contributing to the control of *B. tabaci* (Arnó et al., 2010b). Additionally, it is mass reared and released primarily to control *B. tabaci* and *Tuta absoluta* (Meyrick) (Lepidoptera: Gelechiidae) in tomato greenhouses in southern European countries (Calvo et al., 2009b, 2012). This predator has also been observed to contribute to the control of thrips, leafminers, aphids, spidermites, and Lepidoptera species (Urbaneja et al., 2003; Jacas et al., 2008). In tomato greenhouses, inoculative releases of *N. tenuis* are usually carried out several weeks after transplanting. This strategy is successfully used to control whitefly populations once *N. tenuis* is well established in the crop. However, this strategy does not work in all crop conditions (Gabarra et al., 2008). To reduce the establishment period and improve the distribution of *N. tenuis* in the crop, releases of predators can be made seedling nurseries (Calvo et al., 2010, 2012). Inoculation of *N. tenuis* in the nursery effectively controls both *B. tabaci* and *T. absoluta* (Calvo et al., 2012). However, if the number of *N. tenuis* is too high and prey is scarce, *N. tenuis* can cause plant damage as a result of its phytophagous behaviour (necrotic rings and flower abortion), making regular monitoring necessary to properly manage the *N. tenuis* population (Arnó et al., 2010a).

Orius albidipennis (Reuter), *O. laevigatus* (Fieber) and *O. majusculus* (Reuter) (Hemiptera: Anthocoridae) are widely distributed in the Mediterranean region. These predators are abundant in cucurbit and sweet pepper crops, but not in tomato. Although they are very efficient predators of thrips, they can also complete their life cycle preying upon *B. tabaci* (Castañé et al., 2008).

Pathogens

Three commercially available species of entomopathogenic fungi can be applied as inundative biocontrol strategy against *B. tabaci* (Stansly and Natwick, 2010). These species are *Lecanicillium lecanii* (Zimmerman) Zare and W. Gams, *Paecilomyces fumosoroseus* (Wize) Brown and Smith and *Beauveria bassiana* (Balsamo) Vuillemin. The first two are naturally found infecting *B. tabaci* populations whereas *B. bassiana* has been observed infecting only *B. tabaci* after application (Stansly and Natwick, 2010). For a complete review of entomopathogenic fungi naturally occurring on *B. tabaci* refer to Faria and Wraight (2001). Entomopathogenic fungi can be applied easily and provide significant control of *B. tabaci* (Stansly and Natwick, 2010). These fungi present no risk to human health and have few side-effects on other natural enemies (Goettel et al., 2001)

1.2.9.3. Chemical control

The RRO option chemical control mainly concerns reduction of *B. tabaci* populations. The chemical products available for whitefly control have been classified according to their mode of action, and the Insecticide Resistance Action Committee (IRAC) Mode of Action Classification (www.irac-online.org) has been followed. Not all the pesticides mentioned below are allowed for use in all crops. Several pesticides are still in the phase of registration.

Acetylcholinesterase (AChE) inhibitors: carbamates and organophosphates (Group 1 IRAC Mode of Action Classification)

Carbamates (methomyl, oxamyl) and organophosphates (OP) (chlorpyrifos, chlorpyrifos-methyl, dimethoate, pirimiphos-methyl, etc.) are inhibitors of acetylcholinesterase (AChE), blocking the transmission of nerve impulses (Alon et al., 2008; Houndété et al., 2010; Chung et al., 2011). These compounds are both adulticide and larvicide (Palumbo et al., 2001). Although some of them have been extensively used for whitefly control in the past, nowadays their use has dropped as most field populations exhibit moderate to high resistance (Ahmad et al., 2002; Palumbo et al., 2001; Erdogan et al., 2008; Fernandez et al., 2009; Roditakis et al., 2009; Houndété et al., 2010). Resistance mechanisms involved are insensitive AChE and/or enhanced activity of detoxifying enzymes (Dittrich et al., 1990; Byrne and Devonshire, 1997; Alon et al., 2008).

Sodium channel modulators: pyrethrins, pyrethroids (Group 3A IRAC Mode of Action Classification)

Pyrethrins and pyrethroids (bifenthrin, cypermethrin, lambda-cyhalothrin) act on the insect nervous system, by keeping the voltage-gated sodium channels open, causing insect paralysis and death (Tsagkarakou et al., 2009). Pyrethroids have played a key role in whitefly control because of their efficacy and low persistence (Roditakis et al., 2006). However, owing to widespread resistance (Erdogan et al., 2008; Roditakis et al., 2009; Tsagkarakou et al., 2009; Houndété et al., 2010; Luo et al., 2010), use of pyrethroids against *B. tabaci* has been replaced by other insecticides (Roditakis et al., 2006; Luo et al., 2010). Resistance to pyrethroids has been associated with enhanced metabolic detoxification, by either esterases or monooxygenases (Horowitz et al., 1988; Byrne et al., 2000; Dittrich et al., 1990). In addition, three target site mutations have been reported to confer high levels of pyrethroid resistance (Morin et al., 2002; Alon et al., 2006; Roditakis et al., 2006). Pyrethroid resistance occurs at a similar level in both B and Q biotypes (Luo et al., 2010).

Nicotinic acetylcholine receptor (nAChR) agonists: neonicotinoids (Group 4A IRAC Mode of Action Classification)

Neonicotinoids act as agonists of insect nicotinic acetylcholine receptors (nAChR) (Chao et al., 1997; Zhang et al., 2000; Jeschke and Nauen, 2008). The neonicotinoid compounds currently on the market are imidacloprid, acetamiprid, nitenpyram, thiamethoxam, thiacloprid, clothianidin and dinotefuran (Jeschke and Nauen, 2008). Owing to their physicochemical properties (high water solubility and low partition coefficients), these compounds have an excellent acropetal translocation (systemic) and long-residual efficacy (Palumbo et al., 2001; Jeschke and Nauen, 2008), thereby having a strong insecticidal activity against sucking pests, such as *B. tabaci* (Jeschke and Nauen, 2008). Their uptake and translaminar activity in plants make them particularly versatile in application methods, such as foliar spraying, drip irrigation, soil drenches, seed dressing, injection and painting (Palumbo et al., 2001; Jeschke and Nauen, 2008). Neonicotinoids act on nearly all life stages, but are most toxic to first nymphal instars and adults (Palumbo et al., 2001). Consequently, they have been reported to reduce the incidence of Tomato yellow leaf curl virus (TYLCV) (Ahmad et al., 2002) and Tomato mottle virus (ToMoV) (Stansly et al., 1998). However, the effect is higher on acquisition than on inoculation (Mason et al., 2000), and adults have enough time to inoculate the virus into treated plants before dying (Rubinstein et al., 1999). Therefore, virus management is effective only by large-scale neonicotinoid application resulting in a drastic reduction in the whitefly population (Rubinstein et al., 1999). Resistance to neonicotinoids in *B. tabaci* has been extensively reported (Nauen and Denholm, 2005, and references therein). Although neonicotinoid resistance has been associated with the Q biotype (Horowitz et al., 2005; Fernandez et al., 2009), a few cases have been reported in B-biotype populations (Byrne et al., 2003; Rauch and Nauen, 2003; Nauen and Denholm, 2005). Interestingly, expression of resistance is age specific in B- and Q-biotype strains (Nauen et al., 2008; Jones et al.,

2011). Thus, field resistance is restricted to adults, and resistance expressed in nymphs does not jeopardise insecticide efficacy (Nauen et al., 2008). Cross-resistance among neonicotinoids (Rauch and Nauen, 2003; Prabhaker et al., 2005) and between neonicotinoids and pymetrozine (Gorman et al., 2010) has been described.

Nicotinic acetylcholine receptor (nAChR) agonists: sulfoxaflor (Group 4C IRAC Mode of Action Classification)

Sulfoxaflor is the first compound from the new sulfoxamine class (Zhu et al., 2011). This product acts at insect nicotinic acetylcholine receptors (nAChRs), but through a differential interaction from that of the neonicotinoids (Watson et al., 2011). This compound provides a control similar to other insecticides, including neonicotinoids (Babcock et al., 2011). Existing resistance mechanisms do not affect sulfoxaflor performance, either metabolic (Babcock et al., 2011; Zhu et al., 2011) or target site resistance (Perry et al. 2012).

Juvenile hormone mimics: pyriproxifen (Group 7C IRAC Mode of Action Classification)

Pyriproxifen, a juvenile hormone (JH) mimic, is an efficient insect growth regulator for control of *B. tabaci* immature stages: it suppresses hatching of *B. tabaci* eggs and also affects nymphs, causing mortality before adult emergence (Ishaaya and Horowitz, 1992). Since it has a strong translaminar effect (Ishaaya and Horowitz, 1995), the quality of the application (coverage, deposition under leaf surfaces) does not largely affect its performance (Palumbo et al., 2001). However, it must be targeted at appropriate life stages (eggs and late nymph stages) and population reduction may not be seen before 7-14 days (Palumbo et al., 2001 and references therein). Because it is not toxic to adults, it does not suppress the incidence of *B. tabaci* transmitted virus (Palumbo et al., 2001). Although high resistance to pyriproxifen has been linked to the Q-biotype (Horowitz et al., 2005; Pascual, 2006; Fernández et al., 2009), the B-biotype can also develop resistance (Ma et al., 2010). Because of the potential for rapid development of pyriproxifen resistance in both biotypes, an insecticide resistance strategy has to be followed (Fernández et al., 2009; Ma et al., 2010).

Selective homopteran feeding blockers: pymetrozine (Group 9B IRAC Mode of Action Classification)

Pymetrozine, a pyridine azomethine compound, is a feeding inhibitor causing insects to die within days by starvation (Harrewijn and Kayser, 1997). It has high mobility in plants, being absorbed through leaves, shoots and roots, and translocated through either the xylem or phloem (Wyss and Bolsinger, 1997). These characteristics make pymetrozine less dependent on the quality of the application method. As pymetrozine causes immediate and irreversible cessation of stylet penetration (Harrewijn and Kayser, 1997), it decreases significantly virus transmission by adult whiteflies (Polston and Sherwood, 2003). Moderate to high resistance to pymetrozine has been reported in both B and Q biotypes (Gorman et al., 2010; Qiong et al., 2012). The mechanism involved is overexpression of a P450 monooxygenase showing cross-resistance to neonicotinoids (Gorman et al., 2010; Qiong et al., 2012).

Flonicamid, a pyridinecarboxamide compound, inhibits stylet penetration immediately after treatment, preventing insect feeding and consequently causing death by starvation (Morita et al., 2007). It has been suggested that flonicamid's mode of action is different from that of pymetrozine (Morita et al., 2007).

Inhibitors of chitin biosynthesis, type 1: buprofezin (Group 16 IRAC Mode of Action Classification)

The insect growth regulator buprofezin is a thiadiazine insecticide, and its primary effect is interference with chitin deposition during moulting and so cause nymphal death during ecdysis (Cahill et al., 1996). Its vapour phase activity allows it to act through inhalation (Decock et al., 1990), which means that the application method does not affect its performance to any great extent (Palumbo et al., 2001). As this compound primarily acts on crawlers and second instar nymphs (Beevi and Balasubramanian, 1991), applications must to be targeted at these life stages, and population reduction may not be seen before 7–14 days (Beevi and Balasubramanian, 1991; Palumbo et al., 2001). Since it is not toxic to adults, it does not suppress the incidence of *B. tabaci*-transmitted virus (Palumbo et al.,

2001). Buprofezin resistance has been reported in both the Q biotype (Fernández et al., 2009; Dennehy et al., 2010) and the B biotype (Cahill et al., 1996).

Mitochondrial complex I electron transport inhibitors: METI acaricides and insecticides (Group 21A IRAC Mode of Action Classification)

Pyridaben is a pyridazine compound belonging to the mitochondrial electron transport inhibitor (METI) group (Dekeyser, 2005). It is considered an acaricide, but is active against all stages of some insects, such as whiteflies (Hirata et al., 1995). Pyridaben affects metabolism, inhibiting complex I of the mitochondrial respiratory pathway (Dekeyser, 2005; Van Pottelberge et al., 2009). This compound is commonly used for *Bemisia tabaci* control in some countries (Fernandez et al., 2009). Even field populations highly resistant to other compounds, such as neonicotinoids and IGRs, show a high susceptibility to pyridaben, demonstrating a lack of cross-resistance (Fernandez et al., 2009).

Inhibitors of lipid synthesis: tetrionic and tetramic acid derivatives (Group 23 IRAC Mode of Action Classification)

Spiromesifen is a novel insecticide/acaricide belonging to the new chemical class of tetrionic acid derivatives (Bretschneider et al., 2003; Nauen et al., 2005). It interferes with lipid biosynthesis, inhibiting acetyl-CoA carboxylase (Nauen et al., 2005). Spiromesifen affects egg and immature stage development and decreases female fecundity (Bretschneider et al., 2003). This compound has proved to be an effective tool for whitefly control (Liu, 2004; Prabhaker et al., 2008). Spiromesifen is particularly active against young nymphs (first and second instars), but only slightly toxic to adults (Liu, 2004; Prabhaker et al., 2008; Kontsedalov et al., 2009). This makes a careful selection of application timings necessary (Prabhaker et al., 2008). This compound shows significant systemic activity (Kontsedalov et al., 2009). Resistant B- and Q-biotype populations from several areas have shown no cross-resistance to spiromesifen (Liu, 2004; Prabhaker et al., 2008; Fernandez et al., 2009; Kontsedalov et al., 2009).

Ryanodine receptor modulators: diamides (Group 28 IRAC Mode of Action Classification)

Diamides is a new class of insecticides, consisting of two groups: phthalic (flubendiamide) and anthranilic (chlorantraniliprole and cyantraniliprole) diamides (Lahm et al. 2009). Compounds of the latter group are active against whiteflies, particularly cyantraniliprole (Li et al., 2012a). These insecticides activate the ryanodine receptors, leading to uncontrolled calcium release in muscles (Lahm et al. 2009). Cross-resistance between these compounds and insecticides currently used for whitefly control, such as pyriproxyfen and neonicotinoids, have not yet been reported (Li et al. 2012a).

Compounds of unknown or uncertain mode of action: azadirachtin (Group UN IRAC Mode of Action Classification)

Azadirachtin, a steroid-like tetranortriterpenoid derived from neem trees, is a strong antifeedant, repellent and growth-regulating compound for a variety of pests, including whiteflies (Coudriet et al., 1985; Schmutterer, 1990). In addition, it can cause significant mortality, particularly in nymphs (Kumar and Poehling, 2007). Resistance or cross-resistance has not yet been reported (Fernandez et al., 2009).

Oils

Oils are among the first products to be sprayed to control pests (Butler et al., 1993; Liu and Stansly, 2000). They have a good insecticidal activity, even comparable to conventional insecticides (Liu and Stansly, 2000). They have several advantages over conventional insecticides, such as safety to humans and environment, no known resistance and low cost (Liu and Stansly, 2000). The mode of action is uncertain, and is thought to involve a combination of different chemical and physical effects, including removal of insect cuticle wax, physical action, repellence and cell membrane disruption (Butler et al., 1993). Their contact activity relies on a complete coverage on the leaf surface, requiring proper application methods (Liu and Stansly, 2000).

Soaps

Insecticidal soaps have shown efficacy against *B. tabaci* populations (Butler et al., 1993; Liu and Stansly 1995, 2000). Soaps act by contact; therefore, a perfect coverage on the leaf surface and appropriate deposition are required to achieve effective control (Butler et al., 1993; Liu and Stansly, 2000). In addition, their mode of action remains uncertain, but includes physical action such as desiccation (Liu and Stansly, 1995). Soaps are mainly effective on young nymphs, and have little effect on adults and eggs (Liu and Stansly, 1995). Suitable application methods and environmental conditions are needed for their successful use (Liu and Stansly, 2000).

1.2.9.4. Integrated Pest Management (IPM)

IPM of Bemisia tabaci in cucumber in Spain

Integrated Crop Management (ICM), of which Integrated Pest Management is an element, has been set out in different regulations in most regions of Spain. For Andalucia, there is a specific regulation for integrated production of protected vegetable crops (tomato, pepper, aubergine, bean, courgette, cucumber, melon and watermelon) (Orden de 10 de octubre de 2007). The control measures for whitefly control in cucumber are described at page 151 (BOJA núm. 184 de 20 de septiembre de 2010) and the corresponding description is provided below.

Pest: whitefly, *Bemisia tabaci* and *Trialeurodes vaporariorum*

Intervention criteria/threshold for intervention

Release the natural enemies all over the crop and concentrate them in areas where the pest most likely (re-)infests the crop.

Control methods

- Biological Control Agents (BCAs)
 - *Amblyseius swirskii*: control of *Bemisia tabaci*
 - *Encarsia formosa*: control of *T. vaporariorum*
 - *Eretmocerus eremicus*: control of *T. vaporariorum*
 - *Eretmocerus mundus*: control of *B. tabaci*
 - *Macrolophus pygmaeus* (= *caliginosus*): always with high whitefly populations
- Phytosanitary products (active ingredients)
 - Paraffin oil: Do not make repeated applications if there have been releases of *A. swirskii*. Do not apply when the plant is small and/or treated with sulfur.
 - Azadirachtin.
 - *Beauveria bassiana*: Do not apply with a relative humidity lower than 50%.
 - Oxamyl: 2 weeks before starting *Nesidiocoris* releases.
 - Pymetrozine: Compatible with predatory mites and parasitoids. Wait 2 weeks for antocorids, mirids and coccinelids.
 - Pyrethrins: 2-3 days before BCA releases.
 - Pyridaden: 1-2 weeks before BCA releases. After releases apply only on hot spots, reinforcing with BCA after two weeks.
 - Pyriproxyfen: Do not apply twice in a row during the settling phase of *A. swirskii*.
 - Spiromesifen: reduced to moderate toxicity to phytoseids.
 - Teflubenzuron: Wait 2 weeks for releases with anthocorids, mirids and coccinelids.
 - Thiacloprid: Do not apply if *Orius* is released.
 - Thiamethoxam: Only by drip irrigation, maximum 2 applications spaced 14 days. In the case of *Orius* releases, apply 5 weeks before releasing. When using *Nesidiocoris* apply 3-4 weeks before releasing.

Preventive/cultural measures

- Traps:
 - Yellow sticky traps for monitoring:

- Place them before transplanting at key points
- Maintain them for the whole crop cycle
- Yellow sticky traps for control:
 - Place them before transplanting at a high density
 - Maintain them for the whole crop cycle as long as they do not trap BCAs.

IPM of Bemisia tabaci in tomato in Spain

Integrated Crop Management (ICM), of which Integrated Pest Management is an element, has been set out in different regulations in most regions of Spain. For the Murcia Region, there is a specific regulation for integrated production of tomato crops (Orden de 1 de junio de 2010) and the respective description is provided below.

Pest: Whitefly, *Bemisia tabaci* and *Trialeurodes vaporariorum*

Threshold for intervention

For *T. vaporariorum* when populations are perceived to be increasing.
In the case of *B. tabaci* just after first detection.

Control methods

In case of protected crops the greenhouse needs to be kept as well closed as possible with measures like mesh in the ventilation zones and the use of double doors. To monitor whitefly populations, yellow sticky traps must be placed, with a minimum of 3-5 traps per greenhouse. These traps will be maintained for at least the first 2-3 months after planting. Biological control introductions of *Eretmocerus* spp for the control of *B. tabaci* and other parasitoids and predators in the case of *T. vaporariorum*. These releases can be complemented or substituted by the use of mirid predators. If major problems of *T. vaporariorum* are found or *B. tabaci* is found close to plants with TYLCV symptoms, and the establishment of beneficials is not satisfactory, chemical treatments can be applied following the recommendations of the products listed below. When possible, selective pesticides should be used that are compatible with the biocontrol agents and bumble bees used in tomato.

- Biological Control Agents
 - *Encarsia* spp.
 - *Eretmocerus* spp.
 - *Macrolophus pygmaeus* (= *caliginosus*)
 - *Nesidiocoris tenuis*
 - Other species of generalist predators
- Phytosanitary products (active ingredients):

Before treating with any of these products the compatibility with bumblebees and other beneficials has to be checked. Moreover, the number of treatments per season must be respected.

- Pyriproxyfen
- Pymetrozine
- Imidacloprid: The spray of this active ingredient is only allowed on seedlings before planting and by drip irrigation on young plants.
- Thiamethoxam: The spray of this active ingredient is only allowed on seedlings before planting and by drip irrigation on young plants.
- Paraffin oils: Those are especially authorized for use in this crop, taking extreme precautions, according to the application conditions and possible incompatibilities with other pesticides.
- *Beauveria bassiana*
- Azadirachtin
- Pyridaden
- Pyrethrins authorized in this crop
- Oxamyl: Only by drip irrigation during the first week of the crop

- Teflubenzuron
- Thiacloprid
- Acetamiprid: only on open-field tomatoes
- Spiromesifen
- *Verticillium lecani*

Preventive / cultural measures

- Yellow sticky traps for monitoring

Current situation in the EU:

If signs and symptoms of harmful organisms are detected prior to export, Annex IV of Council Directive 2000/29/EC requires appropriate treatment to ensure pest freedom for the following plants for planting, which are hosts of *B. tabaci* and the viruses it transmits: trees and shrubs (item 39), annual and biennial plants other than *Gramineae* (item 41), herbaceous perennial plants for planting of families *Caryophyllaceae*, *Compositae*, *Cruciferae*, *Leguminosae* and *Rosaceae* (item 44), artificially dwarfed plants (item 43), herbaceous species, *Ficus* spp. and *Hibiscus* (item 45.1). *Solanum lycopersicum* (item 45.3) is specifically considered with respect to *B. tabaci* and TYLCV and appropriate treatment for eradication of *B. tabaci* is required in case of established infestation. Additionally, all plants for planting, originating from countries where viruses transmitted by *B. tabaci* occur (item 46) and where *B. tabaci* is also present should, in case of whitefly infestation, be treated for eradication of the pest. As regards zones protected from *B. tabaci*, infested plants for planting of the genera *Begonia*, *Ficus* and *Hibiscus* (item 24.3) and *Euphorbia pulcherrima* should be subjected to appropriate treatment to ensure pest freedom.

1.2.10. RRO Category 10. Options preventing or reducing infestation in the crop - resistant or less susceptible varieties. Host-plant resistance to *B. tabaci* and/or viruses it transmits

This RRO concerns *B. tabaci* and the viruses it transmits.

Host plant resistance is used here in the sense of Painter (1951), meaning the ability of a certain variety of plant to produce a larger crop of good quality than do ordinary varieties at the same level of pest infestation. Host plant resistance can be based on antixenosis (detering or reducing colonisation by the pest) and antibiosis (killing the pest or reducing its development after being present on the plant) and tolerance (where the number of pest organisms is the same as on a susceptible plant, but the pest does not cause injury). As an RRO, host plant resistance in the form of tolerance is of no interest for *B. tabaci* and its viruses as both the vector and the viruses can survive on plant material.

Innate and induced host plant resistance to pests and diseases can play an important role in reduction of damaging organisms (De Ponti et al., 1990; Nombela and Muniz, 2010; Smith and Clement, 2012). Concerning *B. tabaci*, use of host plant resistance to control this pest and or the viruses it transmits has been proposed by many (e.g. Gerling, 1990; Gerling and Mayer, 1996; Lapidot and Friedman 2002; Morales 2001; Stansly and Naranjo, 2010) and has also been the topic of much pure scientific research. Wild tomato species and cultivars of a number of tomato and other crops have been found that seem (partially) resistant to *Bemisia tabaci* and or the viruses it transmits (for a recent review, see Nombela and Muniz, 2010).

Examples of research providing information about crop cultivars that are (partially) resistant to *Bemisia tabaci* and or the viruses it transmits are squash (*Cucurbita* spp.) (Alves et al., 2005), melon (*Cucumis melo*) (Boisot et al., 2003), eggplant (*Solanum melongena*) (Islam et al., 2010), cotton (*Gossypium hirsutum*) (Jindal and Dhaliwal, 2009), cassava (*Manihot esculenta*), common bean (*Phaseolus vulgaris*), tomato (*Solanum lycopersicum*) (Morales 2001; Nagaraju et al., 2002; Rodriguez-Lopez et al. 2011) and mungbean (*Vigna radiata*) (Qazi et al., 2007). In tomato, various wild relatives of cultivated species have been found with a high degree of resistance to *Bemisia* and a gene has been identified causing this resistance (e.g. Nombela and Muniz, 2010). *Lycopersicon pennellii* LA716, a wild relative of tomato, is resistant to a number of insect pests, including *B. tabaci*,

as a result of the accumulation of acylsugars exuded from type IV trichomes. A positive correlation exists between acylsugar accumulation levels and type IV trichome density, suggesting the possibility that acylsugar levels can be raised by increasing the density of trichomes on the leaf surface (Blauth et al., 1998). As a result of this finding, research was started aiming at breeding commercial tomato lines for resistance to *Bemisia* with introgressions of the wild tomato species *L. pennellii* (Mutschler et al., 2005).

Interestingly, prevention and management of virus-transmitting insects (specifically whiteflies) on horticultural crops was declared officially in 2004 as a public benefit issue in Spain (Nombela and Muniz, 2010). However, apparently limited commercial use of *Bemisia* resistant crops occurs (e.g. Gerling and Mayer, 1996, Stansly and Naranjo, 2010). According to Smith and Clement (2012) “arthropod resistance in most food and fiber crops has not been integrated due primarily to the application of synthetic insecticides”. Nevertheless, Morales (2001) states that “conventional breeding and virus screening techniques have resulted in the release of a large number of begomovirus-resistant cassava, common bean and tomato cultivars”. Virus-resistant tomato cultivars are, for example, used in India (Nagaraju et al., 2002).

Although host plant resistance can be an extremely successful method, development of insect-resistant cultivars often takes more than 10 years of extensive testing (De Ponti et al., 1990). Use of genetic modification to obtain faster results in breeding does not yet seem to be a realistic approach in the EU owing to poor acceptance of this technology by politicians and consumers.

According to many scientific studies, the RRO host plant resistance to *Bemisia tabaci* and its viruses offers great perspective. Tomato cultivars tolerant to virus diseases, sustaining normal growth and fruit production, are commercially available and a basic component of IPM, especially in areas, where *B. tabaci*-transmitted viruses are endemic. Tolerant cultivars have been particularly effective in reducing losses from TYLCV. However, they are not available in many of the varieties preferred by the growers and are not adapted for all production types (Polston and Lapidot, 2007). Host plant resistance to *B. tabaci*, although promising, is still far from field use and, before this RRO will be applicable, substantial applied research will have to be done.

Current situation in the EU:

This option is not addressed in Council Directive 2000/29/EC.

1.2.11. RRO Category 11. Options preventing or reducing infestation in the crop - growing plants under exclusion conditions (glasshouse, screen, isolation)

This RRO concerns both *B. tabaci* and the viruses it transmits.

Growing *B. tabaci* host plants under exclusion conditions may be highly effective in the management of this pest and its associated viruses in both field- and greenhouse-grown crops (Hilje et al., 2001; Stansly and Natwick, 2010). Greenhouses may exclude *B. tabaci* with the use of fine netting in sides, ends and portions of the roof. Netting of a density of 10 threads per cm in the vertical plane and 22 threads per cm in the horizontal plane provides reliable exclusion of *B. tabaci* (openings of approximately 200 by 700 µm) (Hanafi et al., 2007). In addition, some types of plastic and screening contain an ultraviolet-absorbing additive that blocks a greater portion of the ultraviolet light spectrum, maintaining high transmission of visible light. These UV-absorbing films reduce whitefly populations and the incidence of virus compared with conventional materials (Antignus, 2010). However, there is a clear relation between exclusion and ventilation. Finer netting means less air exchange with the outside, resulting often in the occurrence of fungal disease problems (Stansly and Natwick, 2010). This can be solved by using forced ventilation with fans, fogging or a fan and pad evaporation system or by increasing gutter height (Stansly and Natwick, 2010).

In the open field, young plants can be protected from *B. tabaci* during early development by covered structures such as small tunnels covered with fine mesh, thus providing protection through the first critical phase of tomato susceptibility to geminivirus infection (Schuster et al., 1996).

ISPM No 32 (FAO, 2009b) classifies plants for planting as a high pest risk commodity category. The new ISPM No 36 (FAO, 2012) deals with integrated measures applied in production for plants for planting (excluding seeds) for international trade. It provides examples of growing conditions that may affect pest risk, ranked from lower to higher pest risk, as follows: (1) growth chamber; (2) greenhouse; (3) screen house; (4) field grown in containers; (5) field grown; and (6) plants collected from the wild. Enclosures, such as growth chambers, greenhouses and screen houses, provide better opportunity for pest exclusion than outdoor cultivation.

Current situation in the EU:

This option is not addressed in Council Directive 2000/29/EC.

1.2.12. RRO Category 12. Options preventing or reducing infestation in the crop - harvesting of plants at a certain stage of maturity or during a specified time of year

This RRO concerns *B. tabaci* and the viruses it transmits.

Bemisia tabaci and its associated viruses may be present at any vegetative stage of its host plants (Naranjo et al., 2010). *B. tabaci* occurs throughout the year under protected conditions in the whole PRA area and also in the field in warmer climates (e.g. southern parts of Spain, Italy, Greece, and on islands such as Cyprus and Malta). In parts of the Mediterranean area, *B. tabaci* can permanently establish outdoors and develop up to 19 generations per year (Muñiz, 2000b). In regions with colder winters, transient populations may be also present in open fields close to infested protected crops (Bosco and Caciagli, 1998). Therefore, the applicability of this RRO is low.

Current situation in the EU:

This option is not addressed in Council Directive 2000/29/EC.

1.2.13. RRO Category 13. Options preventing or reducing infestation in the crop - certification scheme

This RRO concerns *B. tabaci* and the viruses it transmits.

Important measures to prevent and reduce whitefly and virus infestation in crops are reliable systems to provide pest- and virus-free planting material. Such systems should be compulsory and subject to inspection and certification. Certification schemes are used in various EU countries; we provide one example from Spain.

In several regions of Spain, compulsory inspection and certification systems were established, and have been successfully working for over 10 years. For instance, in Andalusia several control measures were declared compulsory for nurseries to follow in order to prevent virus diseases, such as TYLCV and CVYV transmitted by *B. tabaci*, among others (Orden de 12 de diciembre de 2001, BOJA num. 3 de 8 de enero de 2002).

To make sure provide growers are provided with seedlings free of pests and viruses, nurseries have to fulfil mandatory control measures. There is a wide range of control measures, such as phytosanitary (monitoring and control of virus vectors), structural (greenhouses hermetically closed to insects), prophylactic (early roguing of visibly virus-infected plants) and cultural/agronomic (crop-free periods if necessary).

Nurseries following this regulation are subject to inspection by officials from the regional government, and must be certified to be allowed to grow and sell planting material, both seeds and seedlings.

Current situation in the EU:

This option is not addressed in Council Directive 2000/29/EC.

1.2.14. RRO Category 14. Options ensuring that the area remains free from the pest – maintaining Pest Free Area (PFA)

A pest-free area (PFA) is “an area in which a specific pest does not occur as demonstrated by scientific evidence in which, where appropriate, this condition is being officially maintained (FAO, 1995; ISPM No 4). A pest-free place of production (PFPP) is “a place of production in which a specific pest does not occur as demonstrated by scientific evidence in which, where appropriate, this condition is being officially maintained for a defined period” (FAO, 1999; ISPM No 10). As PFA and PFPP have the same objective and are subject to similar requirements, the Panel merged the information collected for this category. Although PFAs and PFPPs have the same objective, there is a distinction between how these measures are implemented. A PFA is much larger than a PFPP, includes many PFPPs and may cover whole countries. It is usually maintained for many years and is managed as a whole by the NPPO of the exporting country. A PFPP can maintain its status for one or more growing seasons and is managed individually by the producer, under the supervision of the NPPO.

Current situation in the EU

Among the options for introduction and movement of some plants, plants products and other objects into and within all Member States listed in Annex IV, Section I, Part A, of Directive 2000/29/EC there is the possibility of import from PFAs and PFPPs. Usually, the requirement is that either the imported items originate from a PFA or a PFPP or appropriate treatment for eradication and regular inspections to ascertain freedom from *B. tabaci* are implemented. This is the case for herbaceous species, *Ficus* spp. and *Hibiscus* spp. for planting (item 45.1), *Solanum lycopersicum* for planting originating from countries where TYLCV and *B. tabaci* are known to occur (item 45.3.b) and all other plants for planting which originate from countries where viruses transmitted by *B. tabaci* and whitefly are known to occur and appropriate treatments are required (item 46.b). Additionally, one of the options for cut flowers of *Aster* spp., *Eryngium*, *Gypsophila*, *Hypericum*, *Lisianthus*, *Rosa*, *Solidago*, *Trachelium* and leafy vegetables of *Ocimum* (item 45.2) is to obtain these from countries free from *B. tabaci* (in fact, PFA).

Annex Annex IV, Section I, Part B, deals with the movement of plants and plant products originating inside the community. The concern for *B. tabaci* is connected to its ability to transmit TYLCV on *Solanum lycopersicum* (item 26.1). Therefore, if freedom of TYLCV cannot be guaranteed even though no visible symptoms are observed, then *Solanum lycopersicum* for planting must originate from an area or place of production free from *B. tabaci*, or be treated to ensure freedom from the pest.

Section II of Annex IV considers the introduction and movement of plants and plant products into certain protected zones within the EU. For *B. tabaci* these are the entire countries of Ireland, UK, Sweden and Finland and parts of Portugal. The Directive requires that unrooted cuttings (item 24.1) and plants of *Euphorbia pulcherrima* for planting (item 24.2), as well as plants of *Begonia*, *Ficus* and *Hibiscus* for planting (item 24.3) originate from a PFA or PFPP. Alternatively, appropriate treatment for eradication of *B. tabaci* and weekly inspections during the whole production period to ensure pest freedom should be carried out prior to entry into protected zones.

1.2.15. RRO Category 15. Options ensuring that the place or site of production or crop is free from the pest – pest free production site (PFPS)

The situation for pest-free places of production (PFPPs) is the same as for RRO Category 14, and has been discussed in Section 4.2.14.

Current situation in the EU

Council Directive 2000/29 does not provide options with respect to pest-free production sites (PFPS) with respect to *B. tabaci* and the viruses it transmits.

1.2.16. RRO Category 16. Options ensuring that the area, place or site of production or crop is free from the pest – inspections, surveillance

Inspections and surveillance are major elements in reducing the phytosanitary risk of entry of harmful organisms in the PRA area, and they play an important role in many RRO options.

IPPC requires surveillance of areas under cultivation, wild flora, plants and plant products in storage or transportation (Article IV, 2, b), pest-free areas and areas of low pest prevalence (Article IV, 2, e). The IPPC also requires general surveillance for pests in order to identify their status and to develop appropriate phytosanitary measures (Article VII, 2, j). ISPM No 6 (FAO, 1997) provides guidelines for general and specific surveys. Since inspection is always necessary to confirm pest freedom, it is an integral part of several other RROs—establishment of pest-free areas (FAO, 1995; ISPM No 4) and places of production (FAO 1999, ISPM No 10), pre-export check of consignments (FAO 2009a; ISPM No 31) and pre-entry or post-entry quarantine. Systematic surveillance is considered in detail in the guidance of the Scientific Panel on Plant Health on methodology for evaluation of the effectiveness of RRO (EFSA Panel on Plant Health (PLH), 2012). During inspection, whiteflies can be detected by plant sampling or trapping with yellow sticky traps. Combination of the traps with attractive odours could improve trapping efficacy of adult whiteflies (Gorski, 2003). The identification to the species and biotype level is usually based on morphological characteristics or on molecular markers (Bosco et al., 2006). Molecular tools have been developed to detect TYLCV (Navot et al., 1992) and CYSDV and CVYV viruses (Gil-Salas et al., 2007) in *B. tabaci* adults.

Current situation in the EU:

Annex IV, Part A, Section 1 of Directive 2000/29/EC requires the following measures concerning inspection for hosts of *B. tabaci*:

- 1) Inspection prior to export to confirm pest freedom. This measure concern the following plants for planting: trees and shrubs (item 39), annual and biennial plants other than *Gramineae* (item 41), herbaceous perennial plants for planting of families *Caryophyllaceae*, *Compositae*, *Cruciferae*, *Leguminosae* and *Rosaceae* (item 44). If plants for planting of herbaceous species, *Ficus* spp. and *Hibiscus* spp. (item 45.1) are not free of the pest before intended export, they should be subjected to appropriate treatment and officially inspected for nine weeks to confirm pest freedom and allow export. Inspection prior to export also applies to cut flowers of *Aster* spp., *Eryngium*, *Gypsophila*, *Hypericum*, *Lisianthus*, *Rosa*, *Solidago* and *Trachelium* and leafy vegetables of *Ocimum* (item 45.2), in case they originate from countries where *B. tabaci* is present.
- 2) Inspection at least six times a year for naturally or artificially dwarfed plants for planting (item 43).
- 3) Monitoring to ensure freedom from *B. tabaci* and inspection for symptoms of TYLCV are required for *Solanum lycopersicum* for planting (item 45.3) originating from countries where both pests are known to occur. Monitoring of plants for planting through the complete cycle of vegetation to confirm that no symptoms of *B. tabaci*-transmitted viruses are present is required in countries where *B. tabaci* or other vectors are not known to occur (item 46.a). If vectors occur at the country of origin, an official statement that no symptoms have been observed during an adequate period is required.

In Part B of Annex IV of the Directive 2000/29/EC, additional measures are stipulated for the entry of unrooted cuttings (item 24.1) and plants for planting of *Euphorbia pulcherrima* and plants of the genera *Begonia*, *Ficus* and *Hibiscus* in protected zones. If the plants do not originate from a pest-free area, inspection should be carried out throughout the whole production period. When *B. tabaci* has been found at the place of production, it should be subjected to appropriate treatment to ensure pest freedom and weekly official inspections during the whole production period should be carried out, the last one taking place immediately prior to movement.

1.2.17. RRO Category 17. Options for other types of pathways - natural spread, spread by human activities (people movement, transports, machineries, trade), vectors, phoresy

Natural spread of B. tabaci within and between countries



Figure F.1: Left: *Bemisia tabaci* “clouds” in Imperial Valley, California, USA (1990); Right: *B. tabaci* in Murcia, Spain (2012)

As *B. tabaci* immature stages are sessile, except for part of the first nymphal stage, during which crawlers may move a few centimetres, movement to other leaves and to neighbouring plants is rare, and active movement to other fields or areas by immature stages is virtually impossible (van Lenteren and Noldus, 1990). *B. tabaci* adults demonstrate two distinct flight patterns: short- and long-distance flights (Berlinger, 1986). Short-distance flights of a few metres occur under the plant canopy. When host plant quality is good, adult *B. tabaci* will usually not move more than a few centimetres to metres during their lifespan. Short-range flights within and between cultivated and weed host plants may occur.

Long-distance flights occur when adults take off from a host plant, get caught in an air current and drift passively. Take-off from a host plant may be initiated when crop conditions deteriorate and/or when whitefly density is very high (van Lenteren and Noldus, 1990). Massive clouds of passively dispersing *B. tabaci* were observed in cotton in the USA during the 1990s (Naranjo et al., 2010). Passive long-distance dispersal aided by wind may result in spread of whitefly to uninfested fields in the same area or in new areas either in the same country or in neighbouring countries. However, there is no published information on the frequency of long-distance dispersal and its effect on infestation of new areas by *B. tabaci*.

Specific RROs to prevent natural spread of whitefly seem restricted. It would be best to try to reduce *B. tabaci* populations in crops where it is present. When whitefly populations are low, dispersal will be very limited. Options for reduction of whitefly populations are described under RROs 9–11 and 14–16. When large whitefly densities occur at the end of the growth season, it is particularly important to apply elements of RRO 9 to the crop to kill remaining whitefly populations in order to prevent large-scale whitefly dispersal. Newly arriving whiteflies in hitherto uninfested areas can be managed by applying elements of RROs 9, 10, and 11.

Spread by human activities

The main pathways for spread of *B. tabaci* and the viruses it transmits is through human activities by trading plants and plant material. In addition, it is known that travellers may take plant material from one to another country, a largely uncontrolled activity. Importation of plant material infested with (virus-infected) *B. tabaci* may occasionally occur. Import of machinery carrying *B. tabaci* and the viruses it transmits from without the EU seems unlikely and movement of such machinery over long distances within the EU is also not likely.

The only RROs helpful to reduce the risk of import of infested plant material would be categories 1 and 2, and, if these were strictly applied, the risk of importation or movement of infested plant material within the EU would be limited.

Vectors and phoresy

Not applicable

Current situation in the EU:

This option is not addressed in Council Directive 2000/29/EC.

1.2.18. Other relevant information

Not applicable.

1.3. Overview of the risk reduction options

Table F.1: Overview of the risk reduction options

Risk reduction option categories										
Options for		Summary of option	Effect on plant with <i>B. tabaci</i>	Uncertainty	Effect on plant with virus	Uncertainty	Applicability	Feasibility	In EC directive	New aspects
1 Consignment	Prohibition	Prohibition of consignment	Massive	Low	Massive	Low	Low	Low	Yes	Yes
2 Consignment	Pest freedom	Inspection or testing	Massive	low	Major	Low	Medium	High	Yes	Yes
3 Consignment	Prohibition of parts	Prohibition of parts/specific genotypes of the host	Minimal	Low	Minimal	Low	Medium	Low	Yes	No
4 Consignment	Quarantine system	Pre-entry quarantine	Massive	Low	Moderate	Low	High	High	Yes	No
		Post-entry quarantine	Major	Low	Moderate	Low	High	High	Yes	No
5 Consignment	Certificate	Demand for phytosanitary certificate	Major	Low	Moderate	Low	High	High	Yes	No
6 Consignment	Preparation	Preparation of the consignment	Minor	Low	Minimal	Low	Medium	Low	Yes	No
7 Consignment	Treatment	Specified treatment of the consignment	Major	Low	Minimal	Low	Medium	Low	No	
8 Consignment	Use restriction	End use	Minor	Low	Minor	Low	Low	Low	No	
		Distribution	Minimal	Low	Minimal	Low	Low	Low	No	
		Periods of entry	Minimal	Low	Minimal	Low	Low	Low	No	
9 Prevent/reduce	Control methods	Cultural method							Yes	Yes
		Crop-free period	Major	Medium	Major	Medium	High	High		

Risk reduction option categories									
Options for	Summary of option	Effect on plant with <i>B. tabaci</i>	Uncertainty	Effect on plant with virus	Uncertainty	Applicability	Feasibility	In EC directive	New aspects
	Planting date	Minor	Medium	Minor	Low	High	High		
	Sanitation before planting	Major	Medium	Major	Medium	High	High		
	Plant manipulation before planting	Minor	Low	Minimal	Low	High	High		
	Pruning	Minor	Low	Minimal	Low	Medium	Medium		
	Roguing/removal of virus infected plants	Minor	Low	Moderate	Low	High	High		
	Weed management	Minor	Low	Minor	Low	Medium	Medium		
	High planting density	Minimal	Low	Minimal	Low	Low	Low		
	Barriers/mechanical control	Minimal	Low	Minimal	Low	Low	Low		
	Intercropping	Minimal	Low	Minimal	Low	Low	Low		
	Mulching	Moderate	Medium	Minor	Medium	Low	Low		
	Fertilisation/plant nutrition	Minor	Medium	Minimal	Minimal	Low	Low		
	Irrigation/water stress	Minimal	Low	Minimal	Low	Low	Low		
	Overhead irrigation	Minimal	Low	Minimal	Low	Low	Low		
	Sanitation, disposal of crop residues	Major	Low	Major	Low	High	Medium		
	Scouting	Major	Medium	Major	Medium	High	High		
	Biological control¹								
	<i>Encarsia lutea</i>	Minimal	High	Minimal	Low	Low	Low		
	<i>Encarsia pergandiella</i>	Minor	High	Minor	Low	Low	Low		

Risk reduction option categories									
Options for	Summary of option	Effect on plant with <i>B. tabaci</i>	Uncertainty	Effect on plant with virus	Uncertainty	Applicability	Feasibility	In EC directive	New aspects
	<i>Eretmocerus eremicus</i>	Minor	Medium	Minor	Low	Medium	Medium		
	<i>Eretmocerus mundus</i>	Major	Low	Minor	Low	High	High		
	<i>Amblyseius swirskii</i>	Massive	Low	Minor	Low	High	High		
	<i>Coenesia attenuata</i>	Minor	High	Minimal	Low	Low	Low		
	Coccinellids (<i>Delphastus catalinae</i> and <i>Clistothecus arcuatus</i>)	Minimal	High	Minimal	Low	Low	Low		
	<i>Dicyphus tamaninii</i>	Moderate	Medium	Minor	Low	Medium	Medium		
	<i>Macrolophus pygmaeus</i>	Major	Low	Minor	Low	High	High		
	<i>Nesidiocoris tenuis</i>	Massive	Low	Minor	Low	High	High		
	Anthocoridae (<i>Orius</i> spp.)	Minimal	High	Minimal	Low	Low	Low		
	Entomopathogenic fungi	Major	Medium	Minor	Low	High	High		
	Chemical control²								
	Acetylcholinesterase (AChE) inhibitors: carbamates and organophosphates ³	Major	Low	Moderate	Low	High	High		
	Sodium channel modulators: pyrethroids	Moderate	Low	Moderate	Low	High	High		
	Nicotinic acetylcholine receptor (nAChR) agonists: Neonicotinoids	Massive	Low	Major	Low	High	High		
	Nicotinic acetylcholine receptor (nAChR) agonists: sulfoxaflor	Massive	Medium	Moderate	Low	High	High		

Risk reduction option categories										
Options for		Summary of option	Effect on plant with <i>B. tabaci</i>	Uncertainty	Effect on plant with virus	Uncertainty	Applicability	Feasibility	In EC directive	New aspects
		Juvenile hormone mimics: pyriproxifen	Major	Low	Minor	Low	High	High		
		Selective homopteran feeding blockers: pymetrozine	Major	Low	Major	Low	High	High		
		Inhibitors of chitin biosynthesis, type 1: buprofezin	Major	Low	Minor	Low	High	High		
		Mitochondrial complex I electron transport inhibitors	Major	Low	Moderate	Low	High	High		
		Inhibitors of lipid synthesis	Massive	Low	Minor	Low	High	High		
		Ryanodine receptor modulators	Massive	Low	Major	Low	High	High		
		Azadirachtin	Moderate	Medium	Minor	Low	High	High		
		Oils	Moderate	Medium	Minor	Low	High	High		
		Soaps	Moderate	Medium	Minor	Low	High	High		
		Integrated pest management	Massive	Low	Massive	Low	High	High		
10 Prevent/reduce	Host plant resistance	Use of <i>B. tabaci</i>-resistant cultivars	Major	Low	Minor	Low	High	High	No	
		Use of <i>B. tabaci</i>-tolerant cultivars	Minor	Low	Minor	Low	High	High		
		Use of virus-resistant cultivars	Minor	Low	Massive	low	High	High		
		Use of virus-tolerant cultivars	Minor	Low	Minor	Low	High	High		
11 Prevent/reduce	Pest exclusion	Use of greenhouse/screenhouse/cages	Major	Medium	Major	Medium	High	High	No	

Risk reduction option categories											
Options for		Summary of option		Effect on plant with <i>B. tabaci</i>	Uncertainty	Effect on plant with virus	Uncertainty	Applicability	Feasibility	In EC directive	New aspects
12 Prevent/reduce	Harvesting	Timing of planting and/or harvesting		Minimal	Low	Minimal	Low	Low	Low	No	
13 Prevent/reduce	Certification	Demand certificate of pest and virus freedom		Massive	Low	Massive	Low	High	High	Yes	No
14 Pest freedom	Pest-free options	Ensure area remains pest and virus free		Massive	Low	Major	Low	High	High	Yes	No
15 Pest freedom	Pest-free options	Ensure pest- and virus- free production site		Major	Low	Moderate	Low	High	High	Yes	No
16 Pest Freedom	Pest-free options	Ensure pest- and virus-free area by inspection		Major	Low	Moderate	Low	High	high	yes	no
17 Other pathways	Control methods	Limit natural spread		Minor	High	Minor	High	Low	Low	No	
		Limit spread by humans		Moderate	High	Moderate	High	Medium	Low	No	
18 Other information		NA						N/A	N/A	no	

Notes:

Effect of a risk reduction option: ability of an option to reduce the risk caused by a harmful organism.

Applicability: can the method be applied for this crop/cropping situation?

Feasibility: is it expected that the method will be applied (e.g. a method can be very well applied, but is so expensive that the feasibility of application is minimal)?

Rating effect: minimal, minor, moderate or major massive; for descriptors see the text on RROs.

Rating uncertainty: low, medium or high; for descriptors see the text on RROs

Rating applicability and feasibility: low, medium or high; ratings are described in the text section on risk reduction options.

NA, not applicable.

¹Not all natural enemies are effective on all crops.

²Not all chemicals within a mode of action group are equally effective in all cropping situations.

³Not all chemicals are registered for all crops (check registration status).

G. RATINGS AND DESCRIPTORS

In order to follow the principle of transparency as described under Paragraph 3.1 of the Guidance document on the harmonised framework for risk assessment (EFSA Panel on Plant Health (PLH), 2010) – “...*Transparency requires that the scoring system to be used is described in advance. This includes the number of ratings, the description of each rating.... the Panel recognises the need for further development...*” – the Plant Health Panel has developed specifically for this opinion rating descriptors to provide clear justification when a rating is given.

1. Ratings used in the conclusion of the pest risk assessment

In this opinion of EFSA’s Plant Health Panel for the risk assessment of *B. tabaci* and the viruses transmitted by *B. tabaci* for the EU territory and identification and evaluation of risk management options, a rating system of five levels with their respective descriptors has been used to formulate separately the conclusions on entry, establishment, spread, and impact as described in the following tables.

Table G.1: Rating of probability of entry

Rating for entry	Descriptors for <i>B. tabaci</i> and <i>B. tabaci</i> transmitted viruses
<i>Very unlikely</i>	<p>The likelihood of entry would be very low because the pest:</p> <ul style="list-style-type: none"> • is not or only very rarely associated with the pathway at the origin; and/or • cannot survive during transport or storage; and/or • cannot survive the current pest management procedures existing in the risk assessment area; and/or • cannot transfer to a suitable host in the risk assessment area.
<i>Unlikely</i>	<p>The likelihood of entry would be low because the pest:</p> <ul style="list-style-type: none"> • is rarely associated with the pathway at the origin; and/or • survives at a very low rate during transport or storage; and/or • is strongly limited by the current pest management procedures existing in the risk assessment area; and/or • has considerable limitations for transfer to a suitable host in the risk assessment area.
<i>Moderately likely</i>	<p>The likelihood of entry would be moderate because the pest:</p> <ul style="list-style-type: none"> • is relatively frequently associated with the pathway at the origin; and/or • survives at a low rate during transport or storage; and/or • can be affected by the current pest management procedures existing in the risk assessment area; and/or • has some limitations for transfer to a suitable host in the risk assessment area.

<i>Likely</i>	<p>The likelihood of entry would be high because the pest:</p> <ul style="list-style-type: none"> • is regularly associated with the pathway at the origin; <p>and/or</p> <ul style="list-style-type: none"> • mostly survives during transport or storage; <p>and/or</p> <ul style="list-style-type: none"> • is only partially affected by the current pest management procedures existing in the risk assessment area; <p>and/or</p> <ul style="list-style-type: none"> • has very few limitations for transfer to a suitable host in the risk assessment area.
<i>Very likely</i>	<p>The likelihood of entry would be very high because the pest:</p> <ul style="list-style-type: none"> • is very frequently associated with the pathway at the origin; <p>and/or</p> <ul style="list-style-type: none"> • survives during transport or storage; <p>and/or</p> <ul style="list-style-type: none"> • is not affected by the current pest management procedures existing in the risk assessment area; <p>and/or</p> <ul style="list-style-type: none"> • has no limitations for transfer to a suitable host in the risk assessment area.

Table G.2: Rating of probability of establishment

Rating for establishment	Descriptors for <i>B. tabaci</i> and <i>B. tabaci</i> transmitted viruses
<i>Very unlikely</i>	The likelihood of establishment would be very low because of (1) absence or very limited availability of host plants; or (2) environmental conditions that are unsuitable and/or (3) other considerable obstacles to establishment occur.
<i>Unlikely</i>	The likelihood of establishment would be low because even though the host plants are present in the risk assessment area, the environmental conditions are mostly unsuitable and/or other obstacles to establishment occur.
<i>Moderately likely</i>	The likelihood of establishment would be moderate because even though the host plants are present in the risk assessment area, the environmental conditions are frequently unsuitable and/or other obstacles to establishment may occur.
<i>Likely</i>	The likelihood of establishment would be high because host plants are frequently present in the risk assessment area, environmental conditions are frequently suitable and no other obstacles to establishment occur.
<i>Very likely</i>	The likelihood of establishment would be very high because the host plants are frequently present in the risk assessment area, environmental conditions are generally suitable and no other obstacles to establishment occur. Alternatively, the pest has already established in the risk assessment area.

TABLE G.3: Rating of probability of spread

Rating for spread	Descriptors for <i>B. tabaci</i> and <i>B. tabaci</i> transmitted viruses
<i>Very unlikely</i>	<p>The likelihood of spread would be very low because the pest:</p> <ul style="list-style-type: none"> • has only one, specific way to spread (e.g., a specific vector) which is not present in the risk assessment area, <p>and/or</p> <ul style="list-style-type: none"> • highly effective barriers to spread exist, <p>and/or</p> <ul style="list-style-type: none"> • the host is not or only occasionally present in the area of possible spread
<i>Unlikely</i>	<p>The likelihood of spread would be low because the pest:</p> <ul style="list-style-type: none"> • has one to a few specific ways to spread (e.g., specific vectors) and their occurrence in the risk assessment area is occasional, <p>and/or</p> <ul style="list-style-type: none"> • effective barriers to spread exist, <p>and/or</p> <ul style="list-style-type: none"> • the host is not frequently present in the area of possible spread
<i>Moderately likely</i>	<p>The likelihood of spread would be moderate because the pest:</p> <ul style="list-style-type: none"> • has few, specific ways to spread (e.g., specific vectors) and their occurrence in the risk assessment area is limited, <p>and/or</p> <ul style="list-style-type: none"> • effective barriers to spread sometimes exist, <p>and/or</p> <ul style="list-style-type: none"> • the host is moderately present in the area of possible spread
<i>Likely</i>	<p>The likelihood of spread would be high because the pest:</p> <ul style="list-style-type: none"> • has some, unspecific ways to spread, which occur in the risk assessment area, <p>and/or</p> <ul style="list-style-type: none"> • no effective barriers to spread exist, <p>and/or</p> <ul style="list-style-type: none"> • the host is usually present in the area of possible spread
<i>Very likely</i>	<p>The likelihood of spread would be very high because the pest:</p> <ul style="list-style-type: none"> • has multiple, unspecific and highly effective ways to spread, which all occur in the risk assessment area, <p>and/or</p> <ul style="list-style-type: none"> • no effective barriers to spread exist, <p>and/or</p> <ul style="list-style-type: none"> • the host is widely present in the area of possible spread

Table G.4: Rating of magnitude of the potential consequences

Rating for potential consequences	Descriptors for <i>B. tabaci</i> and <i>B. tabaci</i> transmitted viruses
<i>Minimal</i>	Differences in crop production are within normal day to day variation; no additional control measures are required
<i>Minor</i>	Crop production is rarely reduced or at a limited level; additional control measures are rarely necessary.
<i>Moderate</i>	Crop production is occasionally reduced at a limited level; additional control measures are occasionally necessary.
<i>Major</i>	Crop production is frequently reduced at a significant level; additional control measures are frequently necessary.
<i>Massive</i>	Crop production is always or almost always reduced at a very significant level (severe crop losses which compromise the harvest); additional control measures are always necessary.

2. Ratings used for the evaluation of the risk reduction options

The Panel developed the following ratings with their corresponding descriptors for evaluating the effectiveness of the risk reduction options to reduce the level of risk.

Table G.5: Rating of the effectiveness of risk reduction options

Rating	Descriptors
<i>Minimal</i>	The risk reduction option has no practical effect in reducing the probability of entry or establishment or spread, or the potential consequences.
<i>Minor</i>	The risk reduction option reduces, to a limited extent, the probability of entry or establishment or spread, or the potential consequences.
<i>Moderate</i>	The risk reduction option reduces, to a substantial extent, the probability of entry or establishment or spread, or the potential consequences.
<i>Major</i>	The risk reduction option reduces the probability of entry or establishment or spread, or the potential consequences, by a major extent.
<i>Massive</i>	The risk reduction option essentially eliminates the probability of entry or establishment or spread, or any potential consequences.

Table G.6: Rating of the technical feasibility of risk management options

Rating	Descriptors
<i>Low</i>	The feasibility of application of this risk reduction option is minimal
<i>Medium</i>	The feasibility of application of this risk reduction option is moderate
<i>High</i>	The feasibility of application of this risk reduction option is maximal

Table G.8: Ratings for the applicability of risk reduction options

Rating	Descriptors
<i>Low</i>	The risk reduction option can hardly ever be applied
<i>Medium</i>	The risk reduction option can be applied in some situations
<i>High</i>	The risk reduction option can often be applied

3. Ratings used for describing the level of uncertainty

For the risk assessment chapter – entry, establishment, spread and impact – as well as for the evaluation of the effectiveness of the management options, the level of uncertainty has been rated separately, in coherence with the descriptors.

Rating	Descriptors
<i>Low</i>	No or little information or no or few data are missing, incomplete, inconsistent or conflicting. No subjective judgment is introduced. No unpublished data are used.
<i>Medium</i>	Some information is missing or some data are missing, incomplete, inconsistent or conflicting. Subjective judgment is introduced with supporting evidence. Unpublished data are sometimes used.
<i>High</i>	Most information is missing or most data are missing, incomplete, inconsistent or conflicting. Subjective judgment may be introduced without supporting evidence. Unpublished data are frequently used.

H. PERSONAL COMMUNICATIONS

1. Personal communication from Paul De Baro

In May 2012 the Panel sent an e-mail message to Mr. Paul De Barro (Theme Leader for Biosecurity and Invasive Species at CSIRO Ecosystem Sciences Brisbane, Australia) in order to obtain information needed for development of *B. tabaci* distribution map. As response the Panel received a spreadsheet covering the global distribution of *B. tabaci* with the following information:

“The spreadsheet covers in the global distribution where establishment does not involved greenhouses. All locations have lat and long. So, it does not include areas where it occurs in field crops in summer and greenhouses in winter, but not in field crops because it is too cold. It is about 24 months out of date.”

The data provided in the spreadsheet after removing all the information about the distribution where published data are available are reflected in the Appendix C in the table C.2.

Mr. Paul de Barro has been contacted to ask him if he is content with the way his contribution has been entered in the table.

2. Personal communication from Jean Marie Ramel

In February 2013 the Panel sent an e-mail message to Jean-Marie Ramel (Responsible for Entomology, L.S.V., Station d'entomologie, Campus international de Baillarguet, 34988 Montferrier-sur-Lez Cedex) in order to obtain information needed for development of *B. tabaci* distribution map. As response the Panel received a table covering the distribution of *B. tabaci* in France with the following information:

“With the aim to support you by the development of a distribution map of *B. tabaci* in France reflecting the real situation we are ready to send to you the missing coordinates which we have regarding the presence of *B. tabaci* in open field. On the other hand these data are not publicly available and we do not wish that the GPS coordinate would allow the exact localisation of the agricultural unit. For this purpose you can use the mean GPS coordinates (mean localisation representing the district or sub-district of the area as translation of the *B. tabaci* presence in each relevant district in France. This solution allow us to meet our duty to keep confidentiality regarding the owners and tenants who sent to us the insects for identification.”

The data provided in the table after removing all the information about the distribution where published data are available are reflected in the Appendix C in the table C.2.

Jean-Marie Ramel has been contacted to ask her if she is content with the way her contribution has been entered in the table.

Acknowledgements: the Panel wishes to acknowledge Paul de Barro and Jean-Marie Ramel for their contributions.

ABBREVIATIONS

ASL	Africa silverleafing
CV	Circulative Transmitted viruses
DAISIE	Delivering Alien Invasive Species In Europe (DAISIE) project funded by the sixth framework programme of the European Commission (Contract Number: SSPI-CT-2003-511202)
DG	Directorate General
DNA	Deoxyribonucleic acid
EC	European Commission
EFSA	European Food Safety Authority
EPPO	European and Mediterranean Plant Protection Organisation
ELISA	Enzyme-linked immunosorbent assay
EU	European Union
ICTV	International Committee on Taxonomy of Viruses
IPM	Integrated Pest Management
IPPC	International Plant Protection Convention
IRAC	Insecticide Resistance Action Committee
ISPM	International Standards For Phytosanitary Measures
MS	Member State
NAO	North Atlantic Oscillation
NPPO	National Plant Protection Organisation
NV	Non-Circulative Transmitted viruses
PCR	Polymerase Chain Reaction
PFA	Pest Free Area
PFPP	Pest Free Place of Production
PFPS	Pest Free Production Site
PLH	Plant Health
PRA	Pest Risk Assessment
PZ	Protected Zone
RA	Risk assessment
RNA	Ribonucleic acid
RRO	Risk Reduction Option
RT-PCR	Reverse transcription polymerase chain reaction
UK	United Kingdom