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Pest categorisation of *Bagrada hilaris*

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Abstract

The EFSA Panel on Plant Health performed a pest categorisation of *Bagrada hilaris* (Hemiptera: Pentatomidae) for the EU territory. *B. hilaris*, known as the bagrada bug or painted bug, is a polyphagous pest feeding on at least 25 plant families including several economically important brassica crops such as broccoli, cabbage and cauliflower. Other economically important hosts suffering impacts include beans (Fabaceae), wheat and maize (Poaceae). Young plants are particularly vulnerable to adults and nymphs feeding on tender leaves and growing points, which can cause yield losses. *B. hilaris* occurs in Africa and Asia and has spread to North America (USA and Mexico) and South America (Chile) where there are multiple generations per year. It is not widely distributed in the EU but has been established in Malta and on the Italian island of Pantelleria, south west of Sicily, since the 1970s where it is an economically important pest of capers. The reasons why it has not spread further within southern Europe are unknown. *B. hilaris* is not a regulated pest in the EU. It could further enter and spread within the EU via the import and movement of host plants or as a hitchhiking species forming aggregations in conveyances and amongst non-plant traded goods. Host availability and climate suitability suggest that, in addition to Malta and Pantelleria, southern areas of the EU around the Mediterranean would also be suitable for *B. hilaris* establishment. The introduction of *B. hilaris* to other Mediterranean areas of the EU would likely cause impacts in a range of crops, particularly brassicas. Measures to prevent entry and spread are available. *B. hilaris* satisfies all of the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest.

Keywords: Brassicaceae, painted bug, pest risk, plant health, plant pest, quarantine

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1. Introduction

1.1. Background and Terms of Reference as provided by the requestor

1.1.1. Background

The new Plant Health Regulation (EU) 2016/2031, on the protective measures against pests of plants, is applying from 14 December 2019. Conditions are laid down in this legislation in order for pests to qualify for listing as Union quarantine pests, protected zone quarantine pests or Union regulated non-quarantine pests. The lists of the EU regulated pests together with the associated import or internal movement requirements of commodities are included in Commission Implementing Regulation (EU) 2019/2072. Additionally, as stipulated in the Commission Implementing Regulation 2018/2019, certain commodities are provisionally prohibited to enter in the EU (high risk plants, HRP). EFSA is performing the risk assessment of the dossiers submitted by exporting to the EU countries of the HRP commodities, as stipulated in Commission Implementing Regulation 2018/2018. Furthermore, EFSA has evaluated a number of requests from exporting to the EU countries for derogations from specific EU import requirements.

In line with the principles of the new plant health law, the European Commission with the Member States are discussing monthly the reports of the interceptions and the outbreaks of pests notified by the Member States. Notifications of an imminent danger from pests that may fulfil the conditions for inclusion in the list of the Union quarantine pest are included. Furthermore, EFSA has been performing horizon scanning of media and literature.

As a follow-up of the above-mentioned activities (reporting of interceptions and outbreaks, HRP, derogation requests and horizon scanning), a number of pests of concern have been identified. EFSA is requested to provide scientific opinions for these pests, in view of their potential inclusion by the risk manager in the lists of Commission Implementing Regulation (EU) 2019/2072 and the inclusion of risk reduction options for relevant host commodities, when deemed necessary by the risk manager.

1.1.2. Terms of Reference

EFSA is requested, pursuant to Article 29(1) of Regulation (EC) No 178/2002, to provide scientific opinions in the field of plant health.

EFSA is requested to deliver 53 pest categorisations for the pests listed in Annex 1A, 1B, 1D and 1E (for more details see mandate M-2021-00027 on the Open.EFSA portal). Additionally, EFSA is requested to perform pest categorisations for the pests so far not regulated in the EU, identified as pests potentially associated with a commodity in the commodity risk assessments of the HRP dossiers (Annex 1C; for more details see mandate M-2021-00027 on the Open.EFSA portal). Such pest categorisations are needed in the case where there are not available risk assessments for the EU.

When the pests of Annex 1A are qualifying as potential Union quarantine pests, EFSA should proceed to phase 2 risk assessment. The opinions should address entry pathways, spread, establishment, impact and include a risk reduction options analysis.

Additionally, EFSA is requested to develop further the quantitative methodology currently followed for risk assessment, in order to have the possibility to deliver an express risk assessment methodology. Such methodological development should take into account the EFSA Plant Health Panel Guidance on quantitative pest risk assessment and the experience obtained during its implementation for the Union candidate priority pests and for the likelihood of pest freedom at entry for the commodity risk assessment of High Risk Plants.

1.2. Interpretation of the Terms of Reference

Bagrada hilaris is one of a number of pests listed in Annex 1D of the Terms of Reference (ToR) to be subject to pest categorisation to determine whether it fulfils the criteria of a potential Union quarantine pest for the area of the EU excluding Ceuta, Melilla and the outermost regions of Member States referred to in Article 355(1) of the Treaty on the Functioning of the European Union (TFEU), other than Madeira and the Azores, and so inform European Commission decision-making as to its appropriateness for potential inclusion in the lists of pests of Commission Implementing Regulation (EU) 2019/ 2072. If a pest fulfils the criteria to be potentially listed as a Union quarantine pest, risk reduction options will be identified.

2. Data and methodologies

2.1. Data

2.1.1. Information on pest status from NPPOs

In the context of the current mandate, EFSA is preparing pest categorisations for new/emerging pests that are not yet regulated in the EU and for which, when the pest is reported in an MS, an official pest status is not always available. In order to obtain information on the official pest status for *B. hilaris*, EFSA has consulted the NPPOs of Italy and Malta. Information was received from the NPPO of Italy on 9 December 2021, and from the NPPO of Malta on 15 December 2021. The results of this consultation are presented in Section 3.2.2.

2.1.2. Literature search

A literature search on *Bagrada hilaris* was conducted at the beginning of the categorisation in the ISI Web of Science bibliographic database, using the scientific name of the pest as search term. Papers relevant for the pest categorisation were reviewed, and further references and information were obtained from experts, as well as from citations within the references and grey literature.

2.1.3. Database search

Pest information, on host(s) and distribution, was retrieved from the European and Mediterranean Plant Protection Organization (EPPO) Global Database (EPPO, online), the CABI databases and scientific literature databases as referred above in Section 2.1.2.

Data about the import of commodity types that could potentially provide a pathway for the pest to enter the EU and about the area of hosts grown in the EU were obtained from EUROSTAT (Statistical Office of the European Communities).

The Europhyt and TRACES databases were consulted for pest-specific notifications on interceptions and outbreaks. Europhyt is a web-based network run by the Directorate General for Health and Food Safety (DG SANTÉ) of the European Commission as a subproject of PHYSAN (Phyto-Sanitary Controls) specifically concerned with plant health information. TRACES is the European Commission's multilingual online platform for sanitary and phytosanitary certification required for the importation of animals, animal products, food and feed of non-animal origin and plants into the European Union, and the intra-EU trade and EU exports of animals and certain animal products. Up until May 2020, the Europhyt database managed notifications of interceptions of plants or plant products that do not comply with EU legislation, as well as notifications of plant pests detected in the territory of the Member States and the phytosanitary measures taken to eradicate or avoid their spread. The recording of interceptions switched from Europhyt to TRACES in May 2020.

GenBank was searched to determine whether it contained any nucleotide sequences for *B. hilaris* which could be used as reference material for molecular diagnosis. GenBank® (www.ncbi.nlm.nih.gov/genbank/) is a comprehensive publicly available database that as of August 2019 (release version 227) contained over 6.25 trillion base pairs from over 1.6 billion nucleotide sequences for 450,000 formally described species (Sayers et al., 2020).

2.2. Methodologies

The Panel performed the pest categorisation for *B. hilaris*, following guiding principles and steps presented in the EFSA guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018), the EFSA guidance on the use of the weight of evidence approach in scientific assessments (EFSA Scientific Committee, 2017) and the International Standards for Phytosanitary Measures No. 11 (FAO, 2013).

The criteria to be considered when categorising a pest as potential Union quarantine pest (QP) are given in Regulation (EU) 2016/2031 Article 3 and Annex I, Section 1 of the Regulation. Table 1 presents the Regulation (EU) 2016/2031 pest categorisation criteria on which the Panel bases its conclusions. In judging whether a criterion is met the Panel uses its best professional judgement (EFSA Scientific Committee, 2017) by integrating a range of evidence from a variety of sources (as presented above in Section 2.1) to reach an informed conclusion as to whether or not a criterion is satisfied.

The Panel's conclusions are formulated respecting its remit and particularly with regard to the principle of separation between risk assessment and risk management (EFSA founding regulation (EU) No 178/2002); therefore, instead of determining whether the pest is likely to have an unacceptable impact, deemed to be a risk management decision, the Panel will present a summary of the observed impacts in the areas where the pest occurs, and make a judgement about potential likely impacts in the EU. Whilst the Panel may quote impacts reported from areas where the pest occurs in monetary terms, the Panel will seek to express potential EU impacts in terms of yield and quality losses and not in monetary terms, in agreement with the EFSA guidance on quantitative pest risk assessment (EFSA PLH Panel, 2018). Article 3 (d) of Regulation (EU) 2016/2031 refers to unacceptable social impact as a criterion for quarantine pest status. Assessing social impact is outside the remit of the Panel.

Table 1: Pest categorisation criteria under evaluation, as derived from Regulation (EU) 2016/2031 on protective measures against pests of plants (the number of the relevant sections of the pest categorisation is shown in brackets in the first column)

Criterion of pest categorisation	Criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest (article 3)
Identity of the pest (Section 3.1)	Is the identity of the pest clearly defined, or has it been shown to produce consistent symptoms and to be transmissible?
Absence/presence of the pest in the EU territory (Section 3.2)	Is the pest present in the EU territory? If present, is the pest widely distributed within the EU? Describe the pest distribution briefly
Pest potential for entry, establishment and spread in the EU territory (Section 3.4)	Is the pest able to enter into, become established in, and spread within, the EU territory? If yes, briefly list the pathways of entry and spread.
Potential for consequences in the EU territory (Section 3.5)	Would the pests' introduction have an economic or environmental impact on the EU territory?
Available measures (Section 3.6)	Are there measures available to prevent pest entry, establishment, spread or impact?
Conclusion of pest categorisation (Section 4)	A statement as to whether (1) all criteria assessed by EFSA above for consideration as a potential quarantine pest were met and (2) if not, which one(s) were not met.

3. Pest categorisation

3.1. Identity and biology of the pest

3.1.1. Identity and taxonomy

Is the identity of the pest clearly defined, or has it been shown to produce consistent symptoms and/or to be transmissible?

Yes. The identity of the species is established and *Bagrada hilaris* (Burmeister) is the accepted name and authority.

Bagrada hilaris (Burmeister) is an insect in the order Hemiptera, family Pentatomidae (i.e. true bugs). Synonyms include *Bagrada cruciferarum* Kirkaldy and *Bagrada picta* (Fabricius). The name *B. picta* was used more commonly in the literature during the first half of the 20th century and still appears in the 21st century, as does *B. cruciferarum*, although *B. hilaris* is the senior synonym (Bundy et al., 2018).

Two common names for the species appear in the literature, the painted bug and the bagrada bug.

The EPPO code[1] (Griessinger and Roy, 2015; EPPO, 2019) for this species is: BAGRHI (EPPO, online).

[1] An EPPO code, formerly known as a Bayer code, is a unique identifier linked to the name of a plant or plant pest important in agriculture and plant protection. Codes are based on genus and species names. However, if a scientific name is changed, the EPPO code remains the same. This provides a harmonised system to facilitate the management of plant and pest names in computerised databases, as well as data exchange between IT systems (Griessinger and Roy, 2015; EPPO, 2019).

3.1.2. Biology of the pest

The biology of the pest is summarised in Table 2, but where further detail is needed, it is presented in the text below.

The life cycle of *B. hilaris* is fairly typical for true bugs. Mating occurs a few days after adult emergence; females locate males from distance, being attracted to a male pheromone (Guarino et al., 2008). Egg laying takes place 4 or 5 days later (Palumbo et al., 2016). Adults live for about 95 days during which a female can lay 100–200 eggs singly or in small clusters of 2–13 eggs deposited on the stems, underside of leaves, on the flowers of host plants (Howard, 1906; Palumbo et al., 2016) or in the soil close to its hosts (Howard, 1906; Taylor et al., 2014). In regions of South Africa such as the Lowveld and the southern coast, reproduction occurs all year round although development is somewhat slower during the winter; at altitude on the Highveld reproduction does not take place during the winter (Howard, 1906).

Egg development (oviposition to hatching) takes ~ 7½ days at 25°C (Bundy et al., 2018). At 28°C, eggs hatch in approximately 2 days (Palumbo et al., 2016). There are five nymphal stages (Figure 1). At 28°C, nymphs develop in around 33 days. Overall, egg to adult development takes 34 days at 25°C (Bundy et al., 2018) and 18 days at 30°C (Reed et al., 2017). Reed et al. (2017) estimated the threshold temperature for development to be 16.7°C with 285.4 degree-days required to complete development from egg to adult. Table 2 provides examples for development thresholds for different life stages.

Adults and nymphs are active during the day and feed by sucking cell contents from the foliage, growing tips, bud and fruit of hosts. They leave host plants and shelter in the soil and ground debris during the night (Bundy et al., 2018). In Arizona, peak abundance on broccoli and cauliflower crops was reported during the warmest part of the day, when temperatures were between 32 and 42°C; they were least abundant when temperatures were below 20°C (Huang et al., 2013). When disturbed on plants, adults drop to the ground or walk from plants; when the temperature exceeds 30°C adults may fly from plants when disturbed (Huang et al., 2013). Development is significantly reduced below 16°C and above 40°C (Palumbo et al., 2016). Survival rates are highest between 24°C and 33°C (Reed et al., 2017).

B. hilaris can form aggregations that are found in sheltered areas such as in stone walls around fields or in buildings, including domestic suburban homes (Faúndez et al., 2017). In private homes, aggregations can consist of up to 300 individuals (nymphs and adults) (Faúndez, 2018). The development of aggregations in domestic houses occurs during spring and summer months so is not associated with overwintering (Faúndez, 2018), unlike the aggregations of the related invasive species *Halymorpha halys* Stål (Hemiptera: Pentatomidae) which form when they seek overwintering sites (Lee et al., 2014).

B. hilaris is a multivoltine species, in southern Africa, there can be four complete generations and a partial fifth generation each year. In Africa and Asia, the pest thrives in warm dry conditions and the largest populations are found during the dry season (Daiber, 1992) although the pest can be active all year round (Bundy et al., 2018). In the southwest of the USA, populations of *B. hilaris* peak shortly after brassica crops are planted in late August and early September. A second peak occurs during winter months when populations develop on wild cruciferous weeds along roadsides and around the edges of fields (Reed et al., 2013; Joseph et al., 2016). Rain, irrigation and high humidity can reduce abundance of the pest.

In describing the biology of *B. hilaris* on the island of Pantelleria (south-western Italy) in the Mediterranean, Colazza et al. (2004) reported that adults emerge from overwintering sites and become active in May and June, feeding and reproducing on capers (*Capparis spinosa*) and other horticultural crops.

Figure 1: Life stages of the *Bagrada* bug. Credits: Surendra Dara, University of California Cooperative Extension (first three nymphal stages, and adult); Eric Natwick, University of California Cooperative Extension (eggs and fourth nymphal stage)

Table 2: Important features of the life-history strategy of *Bagrada hilaris*

Life stage	Phenology and relation to host	Other relevant information
Egg	Laid on aerial parts of host plants, commonly the underside of leaves, or in the soil. Can be found almost all year round, depending on temperature conditions.	Threshold for egg development is estimated to be from 12.9°C to 17.5°C depending on the model used (Reed et al., 2017).
Nymph	Day active, feeds on leaves and growing tips of hosts; can form large aggregations on hosts, in sheltered areas and inside buildings, found year-round with peaks in dry season and when brassica crops are emerging.	Threshold for overall nymph development is typically 14–18°C depending on the model used (Reed et al., 2017).
Adult	Day active, feeds on leaves and growing tips of hosts; can form large aggregations on hosts, in sheltered areas and inside buildings, found year-round with peaks in dry season and when brassica crops are emerging. Can fly at temperatures above 30°C.	Threshold for overall development (egg to adult) is typically 15–18°C depending on the model used (Reed et al., 2017).

3.1.3. Host range/Species affected

B. hilaris is a polyphagous pest feeding on hosts from at least 25 plant families (Bundy et al., 2018). Members of the Brassicaceae such as broccoli, cabbage, mustards and cauliflower are especially favoured although economically important crops in other families, including Fabaceae (e.g. peas and beans), Poaceae (e.g. wheat) and Solanaceae (e.g. potatoes), are also fed upon (Palumbo and Natwick, 2010; Palumbo et al., 2016; Bundy et al., 2018). Appendix A provides lists of cultivated and wild/weed hosts.

3.1.4. Intraspecific diversity

No intraspecific diversity has been reported for *B. hilaris*.

3.1.5. Detection and identification of the pest

Are detection and identification methods available for the pest?

Yes, *B. hilaris* can be found during visual inspections of imports and in growing crops, morphological keys and molecular methods are available for its identification.

Symptoms

As a true bug, *B. hilaris* feeds by piercing and sucking cell contents from hosts; feeding damage produces circular or star-shaped chlorotic pots or lesions on leaves that become necrotic, leaves can be misshapen and infested plants may be distorted, leaves can shrivel and dry, young plants can be killed (Howard, 1906; Daiber, 1992; Palumbo et al., 2016).

Detection

Palumbo et al. (2016) noted that there were no reliable sampling plans or monitoring tools available for the early detection of *B. hilaris*. Guarino et al. (2018) conducted research that suggested an unidentified diterpene volatile from cauliflowers could be a candidate compound for potential use in a lure for both sexes of adult *B. hilaris* and nymphs. Arif et al. (2020) tested (E)-2-octenyl acetate in lures, but results were disappointing and no lures appear to have been developed commercially.

If *B. hilaris* is suspected, crops should be inspected during the warmest part of the day, when *B. hilaris* is most active; seedlings and newly transplanted brassicas are most susceptible, so these crops should be inspected most carefully. Cotyledons and the underside of leaves should be inspected for adults and nymphs or symptoms of feeding damage (Palumbo et al., 2016).

Identification and description

A key to the genera within the tribe Strachiini, which includes *B. hilaris*, is provided by Rider (2005). Salini (2019) provides a key to economically important genera of Pentatominae from India, which includes *Bagrada*.

The following general description of life stages is based on more detailed morphological descriptions in Howard (1906), Palumbo et al. (2016) and Bundy et al. (2018).

Eggs: barrel-shaped, ~ 0.75 mm × 0.5 mm, cream to light brown turning dark pink or orange before hatching.

Nymphs: There are five nymphal instars, the first is orange -brown and approximately 1 mm long, subsequent instars are dark brown to black with red markings, the fifth nymphal instar is approximately 5 mm.

Adults: generally black, with numerous symmetrically arranged red or orange and/or yellow – white streaks and spots on upper and lower surfaces. Females are the larger sex, up to 7 mm long and 4 mm wide; males around 5 mm long and 3 mm wide.

The black, red or orange and yellow or white markings of *B. hilaris* make it easily distinguishable from most other pentatomids (Bundy et al., 2018).

Molecular diagnostic methods, based on the cytochrome c oxidase I (COI) sequence, are available to identify *B. hilaris*, with a number of accessions in Genbank.

3.2. Pest distribution

3.2.1. Pest distribution outside the EU

B. hilaris is an invasive stink bug from Asia and Africa. It has spread to North and South America and has a limited distribution in Europe (Figure 2; Appendix B).

EPPO GD reports the distribution of *B. hilaris* as incomplete; it may be more widespread in Africa and Asia. Whilst recorded from Chile, *B. hilaris* may be more widespread in South America, and may continue to spread in North America, given the invasive nature of the pest.

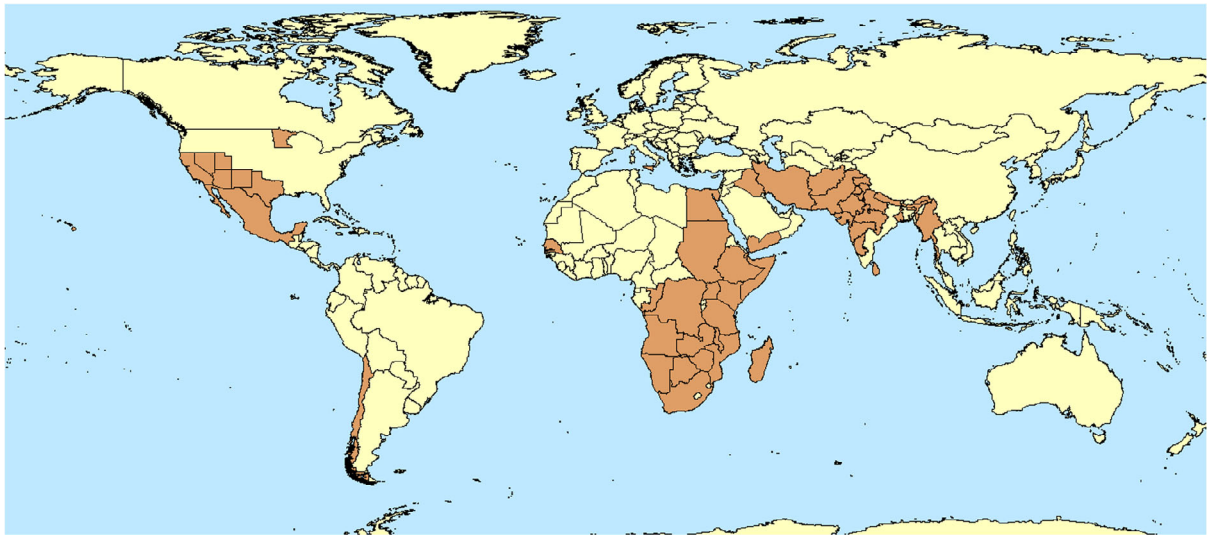

Figure 2: Global distribution of *Bagrada hilaris* (Data Source: CABI, 2016; accessed on 3.10.2021)

3.2.2. Pest distribution in the EU

Is the pest present in the EU territory? If present, is the pest widely distributed within the EU?

Yes, *B. hilaris* occurs in the EU but is not widely distributed. It occurs on Malta and on the Italian island of Pantelleria, south west of Sicily.

B. hilaris has been present in the EU since at least 1978. In compiling a systematic list of Heteroptera of Pantelleria, Carapezza (1981) reported that the Museum of Natural History in Verona had a collection of 60 specimens of *B. hilaris* labelled 'Sicily, Pantelleria 15th Aug 1978'. The specimens were collected from a crop of capers that had been very badly damaged by the infestation. *B. hilaris* is also known from Malta (Carapezza, 1981) where it has been established for over 40 years.

Following consultation, the Italian NPPO confirmed that *B. hilaris* is present on Pantelleria where it has been established for some time; in caper crops, it is controlled by insecticide treatments, due to the harmfulness observed. The situation can be defined as stable. Considering the absence of findings outside Pantelleria and the effectiveness of the treatments, no specific measures have been adopted. The presence of the pest has not been reported in other Italian regions. The status of *B. hilaris* in Italy is regarded as present with restricted distribution: present only in the island of Pantelleria.

The Maltese NPPO confirmed that no measures are applied for *B. hilaris* in Malta.

3.3. Regulatory status

3.3.1. Commission Implementing Regulation 2019/2072

B. hilaris is not listed in Annex II of Commission Implementing Regulation (EU) 2019/2072, an implementing act of Regulation (EU) 2016/2031 or in any emergency measures.

3.3.2. Hosts and species affected that are prohibited from entering the Union from third countries

Table 3: List of plants, plant products and other objects that are *Bagrada hilaris* hosts whose introduction into the Union from certain third countries is prohibited (Source: Commission Implementing Regulation (EU) 2019/2072, Annex VI)

List of plants, plant products and other objects whose introduction into the Union from certain third countries is prohibited			
	Description	**CN Code**	**Third country, group of third countries or specific area of third country**
14.	Plants for planting of the family Poaceae, other than plants of ornamental perennial grasses […] other than seeds	ex 0602 90 50 ex 0602 90 91 ex 0602 90 99	Third countries other than: […]
18.	Plants for planting of Solanaceae other than seeds and the plants covered by entries 15, 16 or 17	ex 0602 90 30 ex 0602 90 45 ex 0602 90 46 ex 0602 90 48 ex 0602 90 50 ex 0602 90 70 ex 0602 90 91 ex 0602 90 99	Third countries other than […]
19.	Soil as such consisting in part of solid organic substances	ex 2530 90 00 ex 3824 99 93	Third countries other than Switzerland

Although *B. hilaris* has been reported feeding on *Solanum tuberosum*, adults and nymphs feed on the leaves not the tubers, so the prohibition of *S. tuberosum* tubers in Annex VI (15, 16 and 17) of 2019/2072 is not relevant.

3.4. Entry, establishment and spread in the EU

3.4.1. Entry

Is the pest able to enter into the EU territory? If yes, identify and list the pathways

Yes, *B. hilaris* could enter the EU via the import of host plants or as a hitchhiking species forming aggregations in conveyances and amongst a variety of manufactured goods.

Comment on plants for planting as a pathway

Plants for planting could be a pathway, for example *B. hilaris* feeds on young brassica plants and many brassica crops as well as other hosts are transplanted into fields as young plants; *B. hilaris* could potentially enter or spread via such young plants.

As noted in Section 3.2.2, *B. hilaris* is already present in the EU and has been for over 40 years. Nevertheless, the species is known as an invasive species and has spread to North and South America. Bundy et al. (2018) noted that *B. hilaris* has been found on castor oil drums imported from India and suggest *B. hilaris* could have been introduced into North America as a hitchhiker via shipping containers rather than via specific plant material. Recall that the related pentatomid *Halyomorpha halys*, the brown marmorated stink bug, has also spread internationally including into the EU, as a hitchhiker with aggregations found for example in sea containers, furniture, cars and with machinery (Duthie et al., 2012).

Table 4: Potential pathways for *Bagrada hilaris* into the EU 27

Pathways	Life stage	Relevant mitigations [e.g. prohibitions (Annex VI) or special requirements (Annex VII) or phytosanitary certificates (Annex XI) within Implementing Regulation 2019/2072]
Plants for planting (excluding seed) especially brassica seedlings/ transplants	Eggs, nymphs, adults on cotyledons and leaves	Phytosanitary certificate required (2019/2072, Annex XI, A, 2.)
Fresh plant produce including multiple species of leafy green vegetables	Eggs, nymphs and adults on leaves	Phytosanitary certificate required (2019/2072, Annex XI, A, 2.)
Sea containers, conveyances, manufactured goods	Aggregations of nymphs and adults	–
Soil	Eggs	Soil from third countries, other than Switzerland prohibited (2019/2072 Annex VI, 19).

B. hilaris is known to be invasive and whilst *B. hilaris* does occur in the USA, it is not known to be present in Florida. *B. hilaris* has been found on trucks transporting plant material across state lines into Florida (LeVeen and Hodges, 2018) e.g. between 2011 and 2013, there were 12 such interceptions at agricultural inspection stations in Florida (no further details are provided in Palumbo et al., 2016). Interceptions of *B. hilaris* also occurred in Hawaii in 2014 and 2015 (Palumbo et al., 2016) and *B. hilaris* is now established in Hawaii on Maui (Matsunaga, 2014).

In the EU, notifications of interceptions of harmful organisms began to be compiled in Europhyt in May 1994 and in TRACES in May 2020. When both databases were searched on 11 October 2021 there was one record of an interception of *B. hilaris* in the Europhyt database:

- *B. hilaris* intercepted in the United Kingdom on lettuce (*Lactuca*) from Kenya, March 1998.

3.4.2. Establishment

Is the pest able to become established in the EU territory?

Yes, *B. hilaris* already occurs in the EU and has been established on islands in the Mediterranean (Malta and Pantelleria (IT)) for at least 40 years. Biotic factors (host availability) and abiotic factors (climate suitability) suggest that other areas of the EU would also be suitable for establishment.

The warmest, driest southern areas of the EU around the Mediterranean where hosts would provide areas where establishment is most suitable; such areas could include parts of Cyprus, southern Greece, southern Italy, southern Portugal, and parts of coastal eastern Spain.

Unless moved with plants for planting, there are uncertainties over the pests' ability to transfer to a suitable host following arrival into the EU. Uncertainties also include its ability to find a mate and other Allee effects (effects causing reduced survival of new colonies with a small number of individuals) (Tobin et al., 2011) as well as the impact of natural enemies in the EU. However, some constraints might be overcome if aggregations consisting of both sexes enter the EU.

Climatic mapping is the principal method for identifying areas that could provide suitable conditions for the establishment of a pest taking key abiotic factors into account (Baker, 2002). Availability of hosts is considered in Section 3.4.2.1. Climatic factors are considered in Section 3.4.2.2.

3.4.2.1. EU distribution of main host plants

B. hilaris is a pest of a range of crops (Appendix A). Most damage is reported from brassica crops. In the EU, the most important brassica vegetables are cauliflower, broccoli and white cabbage. France is the main cauliflower producer, Spain is the most important broccoli producer whilst Hungary, Romania and Poland are the most important producers of white cabbage (EIP-AGRI Focus Group, 2016). The area of brassica crops grown in the EU in recent years is shown in Table 5.

Table 5: EU 27 Area of brassica vegetables (cultivation/harvested/production) (1,000 ha) (Eurostat)

Crop	Code	2016	2017	2018	2019	2020
All brassicas	V1000	247.01	252.60	252.64	266.58	250.46
Cauliflower and broccoli	V1100	114.93	121.88	:	:	:
Cabbages	V1300	97.91	91.98	:	:	:
Radishes	V4500	10.74	11.75	11.29	11.58	11.33
Brussels sprouts	V1200	8.22	8.78	8.83	9.20	8.31

3.4.2.2. Climatic conditions affecting establishment

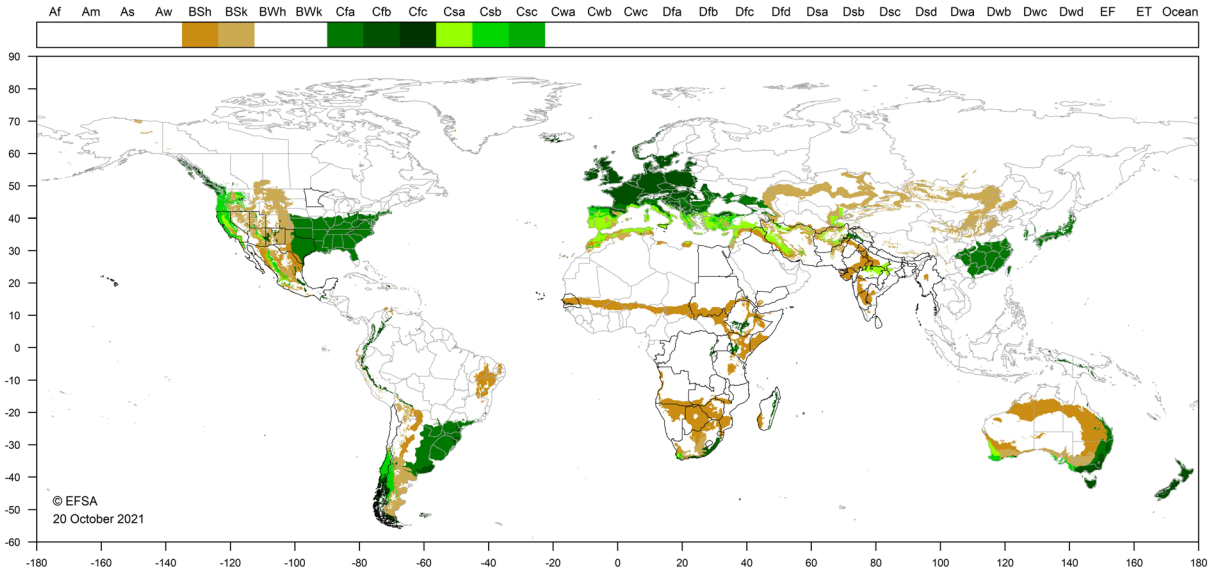

Figure 3: World distribution of eight Köppen–Geiger climate types (BSh, BSk, Cfa, Cfb, Cfc, Csa, Csb and Csc) that occur in the EU and which occur in countries where *Bagrada hilaris* has been reported

Populations of *B. hilaris* develop best in dry warm regions and suffer when temperatures drop below 16°C (Daiber, 1992; Bundy et al., 2018). Some dry climate types that occur in the EU are also found in countries where *B. hilaris* occurs, e.g. BSh (dry, semi-arid, hot) and Csa (temperate, dry, hot summer) as occur in Malta, in addition to other temperate climates (Figure 3). The dry climates represent approximately 10.28% of EU 27 five arc min grid cells (BSh, 0.13%, Csa 10.15%) (MacLeod and Korycinska, 2019).

Colazza et al. (2004) described the biology of *B. hilaris* on Pantelleria where it is a pest of capers. Compared to reports from Asia, Africa and North America females, on Pantelleria live for a shorter time (around 28 days), lay fewer eggs (50–80) and take longer to develop from egg to adults (31–46 days) perhaps indicating that *B. hilaris* is nearing the range of its environmental tolerance on Pantelleria. However, capers are not preferred hosts and should *B. hilaris* be carried to regions of concentrated brassica production in the southern EU, with climate types BSh or Csa, such as Spain, it would likely find conditions suitable for establishment.

Carvajal et al. (2019) used georeferenced location data to model potential global distribution of *B. hilaris* and suggested regions with Mediterranean climates were suitable for establishment. In Europe, Portugal, Spain and the Italian islands in the Mediterranean Sea were judged suitable. However, the map of potential global distribution shows large areas of East Africa and parts of south Asia as unsuitable for *B. hilaris* despite the pest occurring in these regions, undermining the model output presented by Carvajal et al. (2019).

3.4.3. Spread

Describe how the pest would be able to spread within the EU territory following establishment?

B. hilaris nymphs and adults can disperse locally; they move between field edges and crops by walking; at temperatures above 30°C adults can fly for short distances of a few meters. Longer distance spread occurs when adults and nymphs are moved with traded goods, not necessarily plants since the pest can aggregate as hitchhikers on conveyances and manufactured products.

Comment on plants for planting as a mechanism of spread

Many brassica crops are transplanted into fields as young plants (plugs). Such plants are grown from seed in greenhouses but could be placed outside to "harden off" before transplanting. *B. hilaris* could potentially infest young plants in greenhouses or when hardening off outdoors. Spread via plants for planting could then occur when young plants are distributed within the EU.

B. hilaris adults and nymphs can walk; adult flight activity and dispersal is influenced by temperature and Huang et al. (2013) observed adults making short distance flights of 3–6 m during the warmer periods of the day.

In the USA, *B. hilaris* was first reported in southern California in 2008 and was reported in New Mexico in 2012 and further east into Texas by 2013; from southern California it also spread north into Nevada being reported there in 2013 (Taylor et al., 2014). Palumbo et al. (2016) provide a map showing the chronology of county-to-county spread in the south-western USA and suggests that spread follows transportation routes, implicating human involvement facilitating the spread of *B. hilaris*.

Faúndez et al. (2016) first reported *B. hilaris* in Chile in September 2016; at the time it was restricted to a small metropolitan area. Within 5 months, its range had extended 15–30 km from the original site of findings (Faúndez et al., 2017).

Given that the pest has been in the EU for over 40 years and suitable conditions for its establishment are thought to exist elsewhere in the EU, there is uncertainty as to why the pest is not known to have spread from the islands where it is reported (Malta and Pantelleria). A possible explanation is due to the relatively small amount of goods shipped from Malta and Pantelleria to the rest of the EU. Should the pest be introduced into mainland EU it could spread in the warmer and drier parts of the southern EU, as it has in Chile and the south-western USA.

3.5. Impacts

Would the pests' introduction have an economic or environmental impact on the EU territory?

Yes, *B. hilaris* is a recognised economic pest of capers in the EU, on the islands of Pantelleria (IT) and Malta, where capers also grow in the wild. If *B. hilaris* spread to mainland EU economic impacts would be expected to occur in a wider range of crops in the southern EU, particularly brassicas grown in the Mediterranean region.

B. hilaris is a recognised agricultural pest, attacking mostly Brassicaceae although potato, maize, sorghum, capers, some legumes and several weed species are also fed upon (Palumbo and Natwick, 2010, see also Appendix A). Faúndez et al. (2017) reported *B. hilaris* causing 'heavy damage' to unspecified crops grown by small-scale producers in Chile. *B. hilaris* is regarded as a severe pest of brassica crops within its native and invaded range (Reed et al., 2013; Ganjisaffar et al., 2018) and is frequently reported as a pest of brassicas in Botswana, Malawi and Zimbabwe (Odopile et al., 2008; Grzywacz et al., 2010). The pest frequently causes damage when it migrates from weedy hosts around field edges to newly emerging crops grown by direct drilling of seed, or to transplanted brassica crops (Halbert and Eger, 2015; Palumbo et al., 2016). Seedling crops are highly susceptible to direct feeding damage to the cotyledons (Huang et al., 2013) and transplanted brassicas are most vulnerable to *B. hilaris* for the first 5 weeks after planting out (Joseph et al., 2016). Feeding on small plants can cause them to wilt and desiccate. Field observations from the south-western USA report *B. hilaris* adults often invade brassica fields when crops are beginning to emerge, causing serious damage to cotyledons, newly emerged leaves and the growing tips (Palumbo and Natwick, 2010; Huang et al., 2013). Broccoli is particularly susceptible to *B. hilaris* feeding damage (Palumbo and Carriere, 2015).

Female *B. hilaris* feed on hosts for longer causing more damage than males (Huang et al., 2014a). Substantial feeding damage to apical meristems can result in the destruction of growing points resulting in no marketable heads being formed on broccoli, or cabbages with multiple but

unmarketable heads (Palumbo and Natwick, 2010). In the USA, annual losses due to *B. hilaris* are estimated to be in the order of several million US dollars (Joseph et al., 2016) with widespread damage to organically grown crops (Lawrence, 2012).

In an experiment in South Africa, the marketable yield of cabbage was reduced by 67% after a heavy attack by *B. hilaris* (Daiber, 1992). In the USA, it has been estimated that approximately 90% of the planted broccoli area in California and Arizona was infested by *B. hilaris* during 2010 and 2011 leading to yield losses often exceeding 10% (Huang et al., 2014a,b). Elsewhere, Halbert and Eger (2015) reported broccoli growers estimated losses of between 15% and 30%.

Following its introduction and spread in Chile, *B. hilaris* disrupted the conventional pest management regime which was based on high use of chemical pesticides and prompted farmers to switch to IPM (Contesse et al., 2021).

In the EU, in Malta and Pantelleria (IT), *B. hilaris* is a regular and key pest of capers damaging leaves, stems and flower buds (Colazza et al., 2004; Infantino et al., 2007; Cuesta Segura et al., 2010). A damage threshold of 1 bug m^{-2} in the early growing stage of capers and 3 bugs m^{-2} in the successive stages have been suggested (Daiber, 1992).

3.6. Available measures and their limitations

Are there measures available to prevent pest entry, establishment, spread and impact?

Yes, although no specific special requirements against *B. hilaris* are in place, phytosanitary certificates are required to import both plants for planting and plant produce which might carry *B. hilaris* (see Section 3.4.1).

RNQPs: Are there measures available to prevent pest presence on plants for planting such that the risk becomes mitigated?

Yes, host plants could be sourced from pest free areas.

3.6.1. Identification of potential additional measures

Phytosanitary measures (prohibitions) are currently applied to some host plants for planting (see Section 3.3.2). Additional potential risk reduction options and supporting measures are shown in Sections 3.6.1.1 (Table 6) and 3.6.1.2 (Table 7).

3.6.1.1. Additional potential risk reduction options

Table 6: Selected control measures (a full list is available in EFSA PLH Panel, 2018) for pest entry/establishment/spread/impact in relation to currently unregulated hosts and pathways. Control measures are measures that have a direct effect on pest abundance

Control measure/risk reduction option (Blue underline = Zenodo doc, Blue = WIP)	RRO summary	Risk element targeted (entry, establishment, spread impact)
Require pest freedom	Source hosts from pest-free area	Entry, Spread
Growing plants in isolation	*B. hilaris* is not known as a pest of greenhouse crops so brassica vegetable crops could be grown from seed in greenhouses prior to transplanting in fields.	Entry, Spread
Crop rotation, associations and density, weed/volunteer control	Removal of crucifer weeds from field edges might help lower pest populations at origin	Entry, Establishment, Impact
Removal of crop residues after harvest in fields	Removal of hosts will lower populations	Establishment, Spread, Impact
Biological control and behavioural manipulation	In the USA, the egg parasitoid *Gryon gonikopalense* (Hymenoptera: Scelionidae), native to Pakistan, is being evaluated as a biocontrol agent of *B. hilaris* (Martel et al., 2019; Martel and Sforza, 2021).	Entry (when applied at origin) Impact (if applied in EU)
Chemical treatments on crops including reproductive material	Pesticides can provide some control; drenching transplant plugs with systemic insecticides can	Entry, Spread, Impact

Control measure/risk reduction option (Blue underline = Zenodo doc, Blue = WIP)	RRO summary	Risk element targeted (entry, establishment, spread impact)
	protect young plants and reduce impact of *B. hilaris* (Ahuja et al., 2008; Joseph et al., 2016)	
Chemical treatments on consignments or during processing	*B. hilaris* is susceptible to some chemical compounds that may be applied to plants or to plant products after harvest, during process or packaging operations and storage. Treatments could include fumigation and/or spraying/ dipping pesticides (Bundy et al., 2018)	Entry, Spread
Physical treatments on consignments or during processing	Use of irradiation/ionisation radiation and mechanical cleaning (brushing, washing) as well as sorting and grading, prior to export, or movement within the EU, assumed to be options although no specific literature was found in relation to *B. hilaris*.	Entry, Spread
Cleaning and disinfection of facilities, tools and machinery	Businesses could be encouraged to use clean conveyances, such as sea containers, to reduce aggregations of *B. hilaris* from entering or spreading (FAO, 2018a).	Entry, Spread
Heat and cold treatments	As a warmth loving insect, it is expected that *B. hilaris* would be sensitive to cold treatments. Heat treatments above 42°C may also be effective given that the upper lethal temperature is around 42°C (Reed et al., 2017).	Entry, Spread
Conditions of transport	Containers could be inspected and sealed to prevent the entry of aggregations of *B. hilaris*.	Entry, Spread
Controlled atmosphere	Treatment of plants by storage in a modified atmosphere (including modified humidity and pressure, lower O_2, higher CO_2). Cao et al. (2019) reviewed the use of controlled atmospheres as a means to kill insect pests, including Hemiptera, in stored products and during transport. *B. hilaris* is assumed to be susceptible to such treatments.	Entry, Spread

3.6.1.2. Additional supporting measures

Potential additional supporting measures are listed in Table 7.

Table 7: Selected supporting measures (a full list is available in EFSA PLH Panel, 2018) in relation to currently unregulated hosts and pathways. Supporting measures are organisational measures or procedures supporting the choice of appropriate risk reduction options that do not directly affect pest abundance

Supporting measure	Summary	Risk element targeted (entry, establishment, spread impact)
Inspection and trapping	Inspections of material prior to import, on arrival in the EU, and when moving plants for planting within the EU from regions where *B. hilaris* occurs could reduce likelihood of entry or spread.	Entry, Spread
Sampling	Necessary as part of other RROs	

Supporting measure	Summary	Risk element targeted (entry, establishment, spread impact)
Phytosanitary certificate and plant passport	An official paper document or its official electronic equivalent, consistent with the model certificates of the IPPC, attesting that a consignment meets phytosanitary import requirements (ISPM 5). (a) export certificate (import). (b) plant passport (EU internal trade)	Entry (phytosanitary certificate) Spread (plant passport)
Certified and approved premises	If material sourced from an approved premises e.g. in a PFA (Table 6), likelihood of commodity being infested is assumed to be reduced (no specific literature in relation to *B. hilaris*)	Entry, Spread
Delimitation of Buffer zones	As an organism that is already in the EU buffer zones could be used to inhibit spread.	Spread
Surveillance	Surveillance to guarantee that plants and produce originate from a Pest Free Area could be an option.	Entry, Spread

3.6.1.3. Biological or technical factors limiting the effectiveness of measures

- Eggs on plants can be difficult to detect during import inspections
- Eggs can be laid in soil and the soil moved as growing media with plants for planting (spread within EU)
- *B. hilaris* has been reported developing resistance to synthetic insecticides (Guarino et al., 2007)
- Wide host range makes some control options extremely challenging

3.7. Uncertainty

The greatest uncertainty is around why *B. hilaris* is not more widespread within the EU given that the pest has been in the EU for over 40 years and the organism is known to be invasive. Possible explanations could be that the potential pathways for spread from Malta and Pantelleria do not exist, or that the local populations in Malta and Pantelleria have distinct dispersal/invasive characteristics compared to populations elsewhere.

4. Conclusions

B. hilaris satisfies all of the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest. Table 8 provides a summary of the PLH Panel conclusions.

Table 8: The Panel's conclusions on the pest categorisation criteria defined in Regulation (EU) 2016/2031 on protective measures against pests of plants (the number of the relevant sections of the pest categorisation is shown in brackets in the first column)

Criterion of pest categorisation	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Key uncertainties
Identity of the pest (Section 3.1)	The identity of the species is established and *Bagrada hilaris* (Burmeister) is the accepted name and authority.	None
Absence/presence of the pest in the EU (Section 3.2)	*B. hilaris* occurs in the EU but is not widely distributed. It occurs in Malta and on the Italian island of Pantelleria, south west of Sicily.	None
Pest potential for entry, establishment and spread in the EU (Section 3.4)	*B. hilaris* could enter and spread within the EU via the import and movement of host plants or as a hitchhiking species forming aggregations in conveyances and amongst a variety of manufactured goods; in addition to the locations where it is already established in Malta and Pantelleria host availability and climate suitability suggest that other areas of the EU would be suitable for *B. hilaris* establishment.	None

Criterion of pest categorisation	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Key uncertainties
Potential for consequences in the EU (Section 3.5)	*B. hilaris* is a recognised economic pest of capers in Malta and Pantelleria (IT); if *B. hilaris* spread to the mainland, EU economic impacts would be expected to occur in a wider range of crops, particularly brassicas, grown in the Mediterranean region.	None
Available measures (Section 3.6)	Although no specific special requirements against *B. hilaris* are in place, phytosanitary certificates are required to import both plants for planting and plant produce which might carry *B. hilaris*. Measures to prevent spread are available.	None
Conclusion (Section 4)	*B. hilaris* satisfies all of the criteria that are within the remit of EFSA to assess for it to be regarded as a potential Union quarantine pest.	None
Aspects of assessment to focus on/ scenarios to address in future if appropriate:	Reasons to explain why *B. hilaris* has not spread more widely around the Mediterranean.	

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Abbreviations

EPPO	European and Mediterranean Plant Protection Organization
FAO	Food and Agriculture Organization
IPPC	International Plant Protection Convention
ISPM	International Standards for Phytosanitary Measures
MS	Member State
PLH	EFSA Panel on Plant Health
PZ	Protected Zone
TFEU	Treaty on the Functioning of the European Union
ToR	Terms of Reference

Glossary

Containment (of a pest)	Application of phytosanitary measures in and around an infested area to prevent spread of a pest (FAO, 2018b)
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO, 2018b)
Entry (of a pest)	Movement of a pest into an area where it is not yet present, or present but not widely distributed and being officially controlled (FAO, 2018b)
Eradication (of a pest)	Application of phytosanitary measures to eliminate a pest from an area (FAO, 2018b)
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO, 2018b)
Greenhouse	A walk-in, static, closed place of crop production with a usually translucent outer shell, which allows controlled exchange of material and energy with the surroundings and prevents release of plant protection products (PPPs) into the environment.
Hitchhiker	An organism sheltering or transported accidentally via inanimate pathways including with machinery, shipping containers and vehicles; such organisms are also known as contaminating pests or stowaways (Toy and Newfield, 2010).
Impact (of a pest)	The impact of the pest on the crop output and quality and on the environment in the occupied spatial units
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO, 2018b)
Pathway	Any means that allows the entry or spread of a pest (FAO, 2018b)
Phytosanitary measures	Any legislation, regulation or official procedure having the purpose to prevent the introduction or spread of quarantine pests, or to limit the economic impact of regulated non-quarantine pests (FAO, 2018b)
Quarantine pest	A pest of potential economic importance to the area endangered thereby and not yet present there, or present but not widely distributed and being officially controlled (FAO, 2018b)
Risk reduction option (RRO)	A measure acting on pest introduction and/or pest spread and/or the magnitude of the biological impact of the pest should the pest be present. A RRO may become a phytosanitary measure, action or procedure according to the decision of the risk manager
Spread (of a pest)	Expansion of the geographical distribution of a pest within an area (FAO, 2018b)

Appendix A – Bagrada hilaris host plants/species fed upon

Table A.1 lists cultivated host plants or species on which *B. hilaris* has been recorded feeding. Table A.2 lists wild/weed hosts.

Table A.1: Cultivated host plants/species fed upon by *Bagrada hilaris*

Family	Genus/species	Common name	Impact/ damage(1)	Reference
Amaranthaceae	*Beta vulgaris*	Beet		Palumbo et al. (2016)
	Spinacia oleracea	Spinach		Palumbo et al. (2016)
Amaryllidaceae	*Allium cepa*	Onion		Palumbo et al. (2016)
Anacardiaceae	*Mangifera indica*	Mango		Palumbo et al. (2016)
Apiaceae	*Daucus carota* ssp. *sativus*	Carrot		Daiber (1992)
Asteraceae	*Chrysanthemum* sp.	Chrysanthemum		Palumbo et al. (2016)
	Cynara scolymus	Artichoke		Palumbo et al. (2016)
	Dahlia sp.	Dahlia		Palumbo et al. (2016)
	Helianthus annuus	Sunflower	Yes	Reed et al. (2013)
	Lactuca sativa	Lettuce		Daiber (1992)
Brassicaceae	*Brassica juncea*	Indian mustard	High	Reed et al. (2013)
	B. napus	Oilseed rape		Rider (2009)
	B. oleracea (Acephala group)	Kale	High	Reed et al. (2013)
	B. oleracea (Botrytis group)	Cauliflower	High	Reed et al. (2013)
	B. oleracea (Capitata group)	Cabbage	High	Reed et al. (2013)
	B. oleracea (Gemmifera group)	Brussels sprouts		Daiber (1992)
	B. oleracea (Italica group)	Broccoli	High	Reed et al. (2013)
	B. rapa ssp. *rapa*	Turnip		Daiber (1992)
	Eruca sativa	Rocket	High	Reed et al. (2013)
	Hirschfeldia incana	Shortpod Mustard	High	Reed et al. (2013)
	Iberis sp.	Candytuft (ornamental)		Palumbo et al. (2016)
	Matthiola sp.	Aiton Stock (ornamental)		Palumbo et al. (2016)
	Lobularia maritima	Sweet alyssum	High	Reed et al. (2013)
	Nasturtium officinale	Watercress	Yes	Howard (1906)
	Raphanus sativus	Radish		Daiber (1992)
Cannabaceae	*Cannabis sativa*	Hemp		Rider (2009)
Capparaceae	*Capparis* spp.	Capers	High	Infantino et al. (2007)
Caricaceae	*Carica papaya*	Papaya		Palumbo et al. (2016)
Cucurbitaceae	*Momordica dioica*	Spiny gourd		Palumbo et al. (2016)
Euphorbiaceae	*Ricinus communis*	Castor oil plant		Palumbo et al. (2016)
Fabaceae	*Arachis hypogaea*	Peanut		Palumbo et al. (2016)
	Aspalathus linearis	Red bush tea	Secondary pest*	Hatting (2017)
	Medicago sativa	Alfalfa		Palumbo et al. (2016)
	Phaeseolus lunatus	Lima bean	Slight	Reed et al. (2013)
	Phaseolus vulgaris	Snap bean	Slight	Reed et al. (2013)
	Pisum sativum	Pea		Daiber (1992)
	Robinia pseudoacacia	Black locust		Palumbo et al. (2016)
	Trifolium alexandrinum	Egyptian clover		Palumbo et al. (2016)
	Trifolium resupinatum	Persian clover		Palumbo et al. (2016)
	Vicia sp.	Vetch	High	Reed et al. (2013)

Family	Genus/species	Common name	Impact/ damage(1)	Reference
	Vigna unguiculata	Cowpea	Slight	Reed et al. (2013)
Linaceae	*Linum usitatissimum*	Flax		Palumbo et al. (2016)
Malvaceae	*Abelmoschus esculentus*	Okra		Palumbo et al. (2016)
	Gossypium sp.	Cotton	Slight	Reed et al. (2013)
Moraceae	*Morus alba*	Mulberry		Palumbo et al. (2016)
Plantaginaceae	*Plantago major*	Broadleaf plantain		Palumbo et al. (2016)
Poaceae	*Avena sativa*	Oats		Daiber (1992)
	Cynodon dactylon	Bermuda grass		Palumbo et al. (2016)
	Hordeum vulgare	Barley		Daiber (1992)
	Pennisetum glaucum	Pearl millet	Outbreaks	Daiber (1992)
	Saccharum officinarum	Sugar cane		Rider (2009
	Sorghum bicolor v. *sudanense*	Sorghum- Sudan grass	High	Reed et al. (2013)
	Triticum	Wheat	Outbreaks	Daiber (1992)
	Zea mays	Corn, maize	Outbreaks	Palumbo et al. (2016)
Rubiaceae	*Coffea arabica*	Coffee		Palumbo et al. (2016)
Rutaceae	*Citrus* sp.	Citrus		Palumbo et al. (2016)
Solanaceae	*Physalis peruviana*	Cape gooseberry		Palumbo et al. (2016)
	Solanum lycopersicum	Tomato		Palumbo et al. (2016)
	Solanum tuberosum	Potato		Rider (2009)
Theaceae	*Camellia sinensis*	Tea		Palumbo et al. (2016)

*: Hatting (2017) does not define 'secondary pest'. EFSA PLH Panel interpreted this as minor pest.

(1): During laboratory feeding trials, in which adult B. hilaris had access to plants over 5 days, Reed et al. (2013) classified feeding damage on some hosts into three categories: 'Slight' damage was recorded if there was less than five feeding lesions per plant and signs leaves had likely been probed for moisture; 'Yes' damage was recorded when there was more than five feeding lesions per plant but minimal plant damage; 'High' damage was recorded when there was very heavy feeding damage that resulted in wilting and scorching.
'Outbreaks' Palumbo et al. (2016) report that in India, there can be infrequent destructive outbreaks of *B. hilaris* on maize, pearl millet and wheat after more preferred hosts are harvested, the cereals act as 'bridging hosts' when brassica crops are not available.

Table A.2: Wild/weed species fed upon by *Bagrada hilaris*

Family	Genus/species	Common name	Impact/ damage(1)	Reference
Asteraceae	*Geigeria alata*	Wing vomitdaisy		Rider (2009)
	Carduus edelbergii	Thistle (weed)		Palumbo et al. (2016)
	Carthamus oxyacantha	Thistle (weed)		Palumbo et al. (2016)
	Cirsium wallichii	Thistle (weed)		Palumbo et al. (2016)
	Sonchus arvensis	field sowthistle		Rider (2009)
	Xanthium strumarium	Cocklebur		Palumbo et al. (2016)
Brassicaceae	*Cardamine africana*	African bittercress		Howard (1906)
	Capsella bursa-pastoris	Shepherd's purse	High	Reed et al. (2013)
	Descurainia sophia	Flixweed		Palumbo et al. (2016)
	Erucastrum strigosum	Dog mustard		Howard (1906)
	Hirschfeldia incana	Short pod mustard		Palumbo et al. (2016)
Brassicaceae	*Lepidium fremontii*	Desert pepper weed		Rider (2009)
	Lepidium latifolium	Pepper weed		Rider (2009)
	Raphanus raphanistrum	Charlock		Daiber (1992)
	Sisymbrium irio	London rocket	High	Reed et al. (2013)
Capparaceae	*Cleome gynandra*	Stinkweed		Rider (2009)
Chenopodiaceae	*Atriplex lindleyi*	Saltbush		Rider (2009)

Family	Genus/species	Common name	Impact/ damage(1)	Reference
	Chenopodium album	Fat-hen		Rider (2009)
Convolvulaceae	*Convolvulus arvensis*	Field bindweed		Rider (2009)
	Cuscuta reflexa	Dodder		Palumbo et al. (2016)
Cyperaceae	*Cyperus rotundus*	Purple nut sedge		Rider (2009)
Euphorbiaceae	*Chamaesyce hirta*	Asthma plant		Rider (2009)
Fabaceae	*Indigofera arrecta*	Bengal indigo		Rider (2009)
	Medicago polymorpha	Burclover		Palumbo et al. (2016)
Poaceae	*Desmostachya bipinnata*	Halfa grass		Palumbo et al. (2016)
Polygonaceae	*Polygonum plebeiuni*	Knotweed		Rider (2009)
	Rumex dentatus	Toothed dock		Palumbo et al. (2016)
Rhamnaceae	*Zizyphus nummularia*	Wild jujube		Rider (2009)
Solanaceae	*Withania somnifera*	Indian ginseng		Rider (2009)

(1): During laboratory feeding trials, in which adult *B. hilaris* had access to plants over 5 days, Reed et al. (2013) classified feeding damage on some hosts into three categories: 'Slight' damage was recorded if there was less than five feeding lesions per plant and signs leaves had likely been probed for moisture; 'Yes' damage was recorded when there was more than five feeding lesions per plant but minimal plant damage; 'High' damage was recorded when there was very heavy feeding damage that resulted in wilting and scorching.
'Outbreaks' Palumbo et al. (2016) report that in India, there can be infrequent destructive outbreaks of *B. hilaris* on maize, pearl millet and wheat after more preferred hosts are harvested, the cereals act as 'bridging hosts' when brassica crops are not available.

Appendix B – Distribution of Bagrada hilaris

Country and subnational records taken from CABI (2016).

Region	Country	Subnational (e.g. State)	Distribution status
North America	Mexico		Present, restricted distribution
	USA	Arizona, California, Hawaii, Nevada, New Mexico, Texas, Utah	Present, restricted distribution
Central America			No records, presumed absent
Caribbean			No records, presumed absent
South America	Chile		Present, restricted distribution
Europe, EU (27)	Italy	Sicily/Pantelleria	Present, restricted distribution, only on Pantelleria
	Malta		Present, no details
Europe, other			No records, assumed absent
Africa	Angola		Present, no details
	Botswana		Present, no details
	Cape Verde		Present, no details
	D.R. Congo		Present, no details
	Djibouti		Present, no details
	Egypt		Present, no details
	Eritrea		Present, no details
	Ethiopia		Present, no details
	Kenya		Present, no details
	Madagascar		Present, no details
	Malawi		Present, no details
	Mozambique		Present, no details
	Namibia		Present, no details
	Senegal		Present, no details
	Seychelles		Present, no details
	Somalia		Present, no details
	South Africa		Present, no details
	Sudan		Present, no details
	Tanzania		Present, no details
	Uganda		Present, no details
	Zambia		Present, no details
	Zimbabwe		Present, no details
Asia	Afghanistan		Present, no details
	India	Arunachal Pradesh, Assam, Delhi, Gujarat, Haryana, Himachal Pradesh, Jammu and Kashmir, Karnataka, Madhya Pradesh, Maharashtra, Mizoram, Punjab, Rajasthan, West Bengal	Present, no details
	Iran		Present, no details
	Iraq		Present, no details
	Myanmar		Present, no details
	Nepal		Present, no details
	Sri Lanka		Present, no details
	Yemen		Present, no details
Oceania			No records, presumed absent