Netherlands Food and Consumer Product Safety Authority
Ministry of Agriculture, Fisheries, Food Security and Nature

Commodity risk assessment of Fragaria seeds

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Office for Risk assessment & Research (BuRO)

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Abstract

Following a request from the National Plant Protection Organisation of the Netherlands, the Office for Risk assessment & research (BuRO) conducted a Commodity risk assessment of *Fragaria* seeds for the European Union (EU). Plant pests (including pathogens) were identified that can be transmitted through seeds of *Fragaria*. For those seed-transmitted pests that are not regulated in the EU, it was evaluated whether they fulfil the criteria of a Union quarantine pest (EU-Q). Evidence of seed transmission in *Fragaria* was found for five viruses: Arabis mosaic virus (ArMV, *Nepovirus arabis*), beet ringspot virus (BRSV, *Nepovirus betae*), Fragaria chiloensis latent virus (FCiLV, *Ilarvirus FCILV*), raspberry ringspot virus (RpRSV, *Nepovirus rubri*), and strawberry necrotic shock virus (SNSV, *Ilarvirus SNSV*). Limited or inconclusive evidence for seed transmission was found for Fragaria chiloensis cryptic virus (FClCV) and tomato ringspot virus (ToRSV, *Nepovirus lycopersici*). Three out of these seven viruses (BRSV, FCiLV and FClCV) are not regulated in the EU. They do not qualify for a EU-Q status. BRSV may be quite common in the EU because of its long history of presence in Europe and broad host range. For FCiLV and FClCV, no economic impact is expected if they were to establish in the EU. Three of the viruses (ArMV, RpRSV and ToRSV) are Union regulated non-quarantine pests, of which ArMV and RpRSV are regulated for plants for planting (including seeds) of *Fragaria*. SNSV is an EU-Q and special requirements are in place for plants for planting of *Fragaria*, but seeds are exempted from these requirements. No bacterial or fungal pathogens or plant-parasitic nematodes were identified for which seed transmission has been demonstrated in *Fragaria*. A few fungi that are known to infect the strawberry fruit have been found to be seed-borne in *Fragaria* seeds. Cultivated *Fragaria* plants have so far mainly been propagated vegetatively. Consequently, there is little experience available on transmission of pests through *Fragaria* seeds and more pests may be seed-transmitted in *Fragaria* than currently known. Seed transmission of plant-parasitic nematodes seems unlikely because they are not or rarely associated with fruit of *Fragaria*.

Contents

1 Introduction

The National Plant Protection Organisation of the Netherlands has requested the Office for Risk assessment & research (BuRO) to conduct a commodity risk assessment of *Fragaria* (strawberry) seeds. This request was made because propagation by seed is becoming increasingly important in strawberry (Naktuinbouw, 2024; Bentvelsen, 2025). Therefore, it is important to know which pests (including pathogens) of *Fragaria* are seed-transmitted, so that measures can be established to prevent the introduction and spread of these pests through import and movement of *Fragaria* seeds in the European Union (EU).

The 'seeds' of *Fragaria* that are traded and sown are in fact so-called achenes. The edible fleshy strawberry fruit is an 'accessory fruit' with many tiny achenes (approximately 1 mm in length) on the outside (PlantAtlas, 2025). These achenes are dry fruits that do not split open to release the single seed (Ohio Plants, 2025). Pests that colonize the accessory fruit may, therefore, also be associated with the achenes. In this commodity risk assessment, the achenes will be referred to as 'seeds'.

The request included the following specific questions that are addressed in this commodity risk assessment:

- *which pests can be associated with Fragaria seeds (i.e. which pests are seed-borne in Fragaria)?*
- *which of those pests are seed-transmitted in Fragaria?*
- *what is the regulatory status in the EU of the pests that are seed-transmitted in Fragaria?*
- *do the seed-transmittable pests that are not regulated in the EU fulfil the criteria of a Union quarantine pest (EU-Q) (to be assessed by a pest categorization)?*

2 Data and methodologies

2.1 Terminology and abbreviations

2.1.1 Glossary of technical terms used in the document

Contaminating pest	A pest that is not seed-borne but can be present mixed with seeds in storage (FAO, 2021)
Pest	Any species, strain or biotype of plant, animal or pathogenic agent injurious to plants or plant products (FAO, 2021)
Plants for planting	Plants intended to remain planted, to be planted or to be replanted; 'plants' include seeds, in the botanical sense, other than those not intended for planting (Regulation (EU) 2016/2031)[1]
Seed-borne pest	A pest carried by seeds externally or internally that may or may not be transmitted to plants growing from these seeds and cause their infestation (FAO, 2021)
Seed-transmitted pest	A seed-borne pest that is transmitted via seeds directly to plants growing from these seeds and causes their infestation (FAO, 2021)

2.1.2 Abbreviations used in the document

EFSA	European Food Safety Authority https://www.efsa.europa.eu/
EPPO	European and Mediterranean Plant Protection Organisation

[1] Regulation (EU) 2016/2031 of the European Parliament of the Council of 26 October 2016 on protective measures against pests of plants. OJ L 317 23.11.2016, p. 4-104

EU-Q	Union quarantine pest (Regulation (EU) 2016/2031)
LPSN	List of Prokaryotic names with Standing in Nomenclature (Parte et al., 2020)
PZ-Q	Protected zone quarantine pest (Regulation (EU) 2016/2031)
RNQP	Union regulated non-quarantine pest (Regulation (EU) 2016/2031)

2.2 Identification of pests potentially associated with the commodity

A literature search was conducted to identify pests that have been reported to be associated with *Fragaria* seeds. Biological Abstracts 1969 to March 2025 and CAB abstracts 1973 to 2025 Week 14 were searched through Ovid® using the search string '(Fragaria OR strawberry) AND (seedborne OR seed-borne OR seed-transmitted OR (seed AND (transmission OR transmitted OR transmissible)' (in a preliminary search the term 'achene' did not yield more papers with relevant information). In addition, literature and databases were searched to identify regulated and non-regulated pests that infect *Fragaria* and may potentially be seed-borne (and seed-transmitted) in *Fragaria*. The following sources were used for specific groups of pests:

For regulated pests:

- EU-Qs, PZ-Qs and pests regulated by (national) temporary measures are listed in 'Register Q-organismen' on the website of the NVWA (NVWA, 2025). Pests that are known to infect plants of *Fragaria* were subsequently selected using the lists of host plants in the EPPO Global Database (EPPO, 2025b) and the CABI Compendium (CABI, 2025). RNQPs that are regulated for plants for planting of *Fragaria* were identified in Annex IV of Implementing regulation (EU) 2019/2072[2].

For all pest groups:

- EPPO Global Database (EPPO, 2025b): a search for all pests of '*Fragaria* x *ananassa*' and '*Fragaria*' listed in the database was made (a search for all pests of '*Fragaria'* only yielded a much shorter list of pests). The list of pests in the EPPO Global Database reflects the pest-specific information that has been produced or collected by EPPO, and is not complete and, therefore, additional searches were made per group of organisms (bacteria, fungi and oomycetes, nematodes and viruses and viroids) as described below.

For bacteria:

- Biological Abstracts 1969 to February 2025 and CAB abstracts 1973 to 2025 Week 11 were searched through Ovid® using the search string '(Fragaria OR strawberry) AND (Acidovorax OR Agrobacterium OR Liberibacter OR Clavibacter OR Curtobacterium OR Dickeya OR Erwinia OR Pantoea OR Paraburkholderia OR Pectobacterium OR Phlomobacter OR Pseudomonas OR Ralstonia OR Rhodococcus OR Spiroplasma OR Xanthomonas OR Xylophilus OR Xylella)'. This search string will identify all members of genera that contain bacteria which are currently EU-Qs or RNQPs in the EU or are mentioned in the EPPO A1/A2 lists.
- Biological Abstracts 1969 to February 2025 and CAB abstracts 1973 to 2025 Week 11 were searched through Ovid® using the search string '(Fragaria OR strawberry) AND (bacterial blight OR bacterial canker OR bacterial leaf blight OR bacterial leaf spot OR bacterial speck OR bacterial spot OR bacterial wilt)'. This search string focuses on typical symptoms related to bacterial infections.
- Only bacteria that were mentioned to be pathogenic in *Fragaria* in the identified papers were included in the list of pests.

For fungi and oomycetes:

- A list of fungal pathogens (including oomycetes) in a review of 'Fungal diseases of strawberry and their diagnosis' by Garrido et al. (2016). More fungi and oomycetes have been found associated with strawberry (USDA, 2025) but the list of Garrido et al. (2016) presumably

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[2] Commission Implementing Regulation (EU) 2019/2072 of 28 November 2019 establishing uniform conditions for the implementation of Regulation (EU) 2016/2031 of the European Parliament and the Council, as regards protective measures against pests of plants. OJ L 319, 10.12.2019, p. 1-258

contains the most common fungal pathogens of strawberry and was considered sufficient for the objectives of the present study.

For nematodes (limited to foliar and stem nematodes):

- Biological Abstracts from 1969 to February 2025 and CAB abstracts from 1973 to 2025 Week 11 were searched through Ovid® for nematodes colonizing above ground plant parts of *Fragaria* other than *Ditylenchus dipsaci* using the search string '(Fragaria OR strawberry) AND (nematode OR nematodes) AND ((foliar OR stem) NOT dipsaci)'. *Ditylenchus dipsaci* was excluded from the search to keep the number of papers to a manageable number, but was included in the list of pests because it is known as a pest of *Fragaria* and is an RNQP for plants for planting of *Fragaria* (and *Ribes*).

For viruses and viroids:

- The inventory of viruses of *Cydonia* Mill., *Fragaria* L., *Malus* Mill., *Prunus* L., *Pyrus* L., *Ribes* L., *Rubus* L. and *Vitis* L. made by the EFSA Panel on Plant Health et al. (2019b). This study includes a list of all viruses and viroids of *Fragaria* that have been reported up to 19 March 2018.
- A literature search was conducted to identify new viruses and viroids reported to be associated with *Fragaria* since 19 March 2018. Therefore, Biological Abstracts was searched from January 2018 to March 2025 and CAB abstracts from January 2018 to 2025 Week 14 through Ovid® using the search string '(*virus OR *viroid) AND (Fragaria OR strawberry)'.

2.2.1 Organisms excluded

The following organisms were excluded from the assessment:

- Insects and mites: a preliminary literature search for seed-borne pests of *Fragaria* did not yield any insect or mite species. Furthermore, seeds of *Fragaria* are small; sizes in PlantAtlas (2025) are 1.3 mm in length and 1.1 mm in width. Therefore, any contaminating insects and mites are expected to be removed during harvesting and cleaning of the seeds.
- Fungi of the genera *Pichia, Saccharomyces* and *Zygosaccharomyces* that are known to cause postharvest rots in strawberry (Garrido et al., 2016). These pathogens (also known as yeasts) are unlikely to be seed-transmitted.
- Nematodes that only colonize or affect below ground parts and are, therefore, unlikely to be spread by seeds (e.g. *Meloidogyne*, *Pratylenchus* and *Xiphinema* spp.).
- Phytoplasmas: a few phytoplasmas are seed-transmitted according to Kirdat et al. (2022). These phytoplasmas are not known to infect plants of *Fragaria* (Calari et al., 2011; Kirdat et al., 2022). Seed-transmission of phytoplasmas has also been debated (Wei & Zhao, 2025). In addition, no publications of seed transmission were found for phytoplasmas in relation to strawberry in a pilot literature search (Biological Abstracts 1969 to March 2025 and CAB abstracts 1973 to 2025 Week 14 were searched for seed-transmitted pests of *Fragaria* using the search string '(Fragaria OR strawberry) AND (seedborne OR seed-borne OR seed-transmitted OR (seed AND (transmission OR transmitted OR transmissible)) in Ovid®).

2.2.2 Preferred names

The preferred name of each organism was verified using the EPPO Global Database (EPPO, 2025b). All identified nematodes were included in the EPPO Global Database but for fungi and oomycetes and bacteria that were not included in this database, MycoBank (2025) and the List of Prokaryotic names with Standing in Nomenclature (LPSN) (Parte et al., 2020) were used, respectively. For viruses and viroids the database of the International Committee on Taxonomy of Viruses (ICTV, 2025b) was used next to the EPPO Global Database. If the name of the virus or viroid was not included in these databases, the name mentioned in the publication was used.

2.2.3 Seed-borne and seed transmission

BuRO used the sources listed below to get information on whether a pest is seed-borne and seed-transmitted in *Fragaria* or other plants species. Pests, particularly bacteria, fungi and oomycetes, that are known to cause fruit diseases in *Fragaria* (other than *Pichia, Saccharomyces* and *Zygosaccharomyces* species; see section 2.2.1) were identified because these pests may be associated with the seeds.

In the assessment, a pest was considered seed-borne or seed-transmitted in *Fragaria* if the presence of the pest on/in seeds or seed transmission had been demonstrated in at least one *Fragaria* species. Cultivated *Fragaria* plants have so far mainly been propagated vegetatively and more pests may be seed-transmitted in *Fragaria* than currently known. Therefore, if no evidence was found for being seed-borne or seed-transmitted in *Fragaria*, information on other host plants of the pest was searched using the sources mentioned before for *Fragaria*. The search on other host plants was terminated when at least one other host plants was found in which seed transmission had been shown.

Sources:

- Datasheets of the pests in the EPPO Global Database and the CABI compendium and relevant references included in these datasheets (CABI, 2025; EPPO, 2025b).
- The following review papers and books:
  - 'New insights in the study of strawberry fungal pathogens' by Garrido et al. (2011) which included a list of fruit infecting fungi and oomycetes;
  - 'An annotated list of seed-borne diseases' by Richardson (1990);
  - 'Seed-borne plant virus diseases' by Sastry (2013);
  - 'Encyclopedia of plant viruses and viroids' by Sastry et al. (2019).
- Biological Abstracts 1969 to March 2025 and CAB abstracts 1973 to 2025 Week 14 were searched through Ovid® using the search strings:
  - '[name of the pest] and (seedborne or seed-borne or seed-transmitted or (seed and (transmission or transmitted or transmissible)))' to find any host of which the seeds have been found associated with the pest. For pests that yielded no results the search string '[name of the pest] and seed*' was used.
- Recent risk assessments of viruses infecting *Fragaria* including information on seed transmission (not available for other groups of pests):
  - pest categorisation of non-EU viruses of *Fragaria* L. from the EFSA Panel on Plant Health et al. (2019a),
  - scientific opinion on the risk to plant health posed by Arabis mosaic virus, raspberry ringspot virus, strawberry latent ringspot virus and tomato black ring virus to the EU territory with the identification and evaluation of risk reduction options (EFSA-Panel-on-Plant-Health, 2013).

Datasheets, review papers, reference books and risk assessments listed above were used to find original research papers that provide evidence for seed transmission of a particular pest.

3 Results and discussion

3.1 List of pests of Fragaria

All regulated and non-regulated organisms that were identified as pests of *Fragaria* and included for further study are listed in Annex A. Results are discussed below for each group of organisms:

- bacteria,
- fungi and oomycetes,
- nematodes,
- viruses and viroids.

3.2 Bacteria

No bacterial pathogens of *Fragaria* were identified that are known to be seed-borne in *Fragaria*.

Three bacterial pathogens of *Fragaria* were identified that are known to be seed-borne in other plant species: *Pantoea ananatis, Ralstonia pseudosolanacearum* and *Rhodococcus fascians*.

Pantoea ananatis is seed-borne in various host plants including onion (*Allium cepa*), maize (*Zea mays*) and Sudangrass (*Sorghum sudanense*) (Azad et al., 2000; Walcott et al., 2002; Rijavec et al., 2007). Walcott et al. (2002) could recover *P. anatatis* from onion seedlings. However, the seedlings were grown in Petri dishes and seed transmission studies under more natural conditions may be needed for confirmation that *P. anatatis* is indeed seed-transmitted in onion. No further evidence was found for seed transmission of *P. anatatis*.

Ralstonia pseudosolanacearum has more than 100 host plant species from different plant families and seed transmission has been reported in a few of its host plants (EFSA Panel on Plant Health et al., 2019). *Ralstonia pseudosolanacearum* (EU-Q) has been found to be seed-borne (and seed-transmitted) in groundnut (*Arachis hypogea*), tomato (*Solanum lycopersicum*) and eggplant (*S. melongena)* (Machmud & Middleton, 1990; Zhang et al., 1993; Sumithra et al., 2000; Dey et al., 2024). The bacterium has also been reported from *Capsicum* (pepper) seeds and seed transmission has been found through artificially infested *Capsicum* seeds (Preeti Aggarwal & Sood, 2005; Umesha et al., 2005). Seeds of *A. hypogea* appear to become infected by *R. pseudosolanacearum* (Machmud & Middleton, 1990; Zhang et al., 1993). The bacteria may, however, only be present externally on seeds of tomato and eggplant (and possibly pepper) because chemical seed treatments were able to eliminate the bacterium from tomato and eggplant seeds (Dey et al., 2024). It should be noted that there is some uncertainty whether the species reported in the publications referred to above is *R. pseudosolanacearum* or the related species *R. solanacearum*. They are both members of the *Ralstonia solanacearum* species complex that was split into different species including *R. solanacearum* and *R. pseudosolanacearum* in 2014 (Safni et al., 2014).

Rhodoccus fascians has many host plant species belonging to 87 genera and has been found to be seed-borne in some of these hosts (Putnam & Miller, 2007). It may also be seed-transmitted in these hosts. There is for example circumstantial evidence that *R. fascians* is seed-transmitted in *Lathyrus odoratus*. In preliminary experiments on the infectiousness of fasciation symptoms, Tilford (1936) found that a particular seed lot of *L. odoratus* always produced some diseased plants; the use of disfinfested seeds from this lot resulted in no diseased plants. Lacey (1939) found two out of 54 seedlings of *Schizanthus retusus* infected by *R. fascians* after sowing seeds in sterilized soil.

One bacterial pathogen was identified that causes a fruit disease in *Fragaria*: *Erwinia pyrifoliae.* This pathogen may also be present on seeds from infected plants because the seeds (achenes) are present on the accessory fruit (see the 'Introduction). *Erwinia pyrifoliae* can be transported by honey bees (Wenneker, 2022) but seed transmission has not been reported.

3.3 Fungi and oomycetes

3.3.1 List of fungi and oomycetes

A list of fungi and oomycetes that infect *Fragaria* is provided by Garrido et al. (2016). Some of these fungi and oomycetes were, however, excluded from the assessment because of uncertainty about the host status of *Fragaria*:

- *Peronospora potentillae*: Garrido et al. (2016) refer to Choi et al. (2009) for *P. potentillae* being a pathogen of *Fragaria*. However, Choi et al. (2009) describe other *Peronospora* species which infect *Salvia* and no evidence was provided that *P. potentillia* infects *Fragaria*. Douglas Gubler & Converse (1993) indicate *P. fragariae* as a synonym of *P. potentillia*, but *P. sparsa* is currently the preferred name of *P. fragariae* according to EPPO (2025b) and *Fragaria* is not included in the host list of *P. sparsa* in CABI (2020) (EPPO (2025b) does not provide a host list of *P. sparsa*).
- *Sphaeropsis malorum*: *S. malorum* is known as a pathogen of apple (*Malus domestica*) (Grove et al., 2003). No studies were found on *S. malorum* affecting *Fragaria*. Douglas Gubler & Converse (1993) indicate *Botryosphaeria obtusa* (current preferred name: *Diplodia serrata*) as a teleomorph of *S. malorum*. However, *Fragaria* is not listed as a host of *Diplodia serrata* either (Reeder, 2020).

Sphaerotheca macularis was replaced by *Podosphaera aphanis*:

- Garrido et al. (2016) list *Sphaerotheca macularis* as the causal agent of powdery mildew of *Fragaria*. However, the current preferred name of *S. macularis* is *Podosphaera macularis* which is not known as a pest of *Fragaria* (CABI, 2021d). *Podosphaera aphanis* is currently known as the causal agent of powdery mildew in *Fragaria* (CABI, 2021e) and was included in the list of species (Annex A). This species is an RNQP for plants for planting of *Fragaria* (Implementing Regulation (EU) 2019/2072).

Some *Colletotrichum* species were added to the list of Garrido et al. (2016) due to changes in the systematics of this genus:

- Three *Colletotrichum* species, *C. acutatum*, *C. gloeossporioides* and *C. fragariae,* are listed by Garrido et al. (2016). *Colletotrichum acutatum* and *C. gloeossporioides* are, however, species complexes (Rose & Damm, 2024). The species complex *Colletotrichum acutatum* s.l. (= *sensu lato*) is an RNQP for plants for planting of *Fragaria* (the EPPO-code 'COLLAC' in the EU-legislation refers to the species complex). For these reasons, BuRO included the following three categories within the genus *Colletotrichum*: *C. fragariae, Colletotrichum acutatum* s.l. and *Colletotrichum spp.* other than *C. acutatum* s.l. and *C. fragariae*.

3.3.2 Seed-borne and seed transmission

No plant pathogenic fungi or oomycetes were identified as being seed-transmitted in *Fragaria* but a few plant pathogenic fungi and oomycetes have been reported from *Fragaria* seeds (i.e. being seed-borne in *Fragaria*). CABI (2021f) states that *Colletotrichum* spp. are frequently isolated from *Fragaria* seeds and Naktuinbouw (pers. comm., 5 November 2025) has detected *Colletotrichum acutatum* s.l., *Colletotrichum gloeosporioides* s.l., *Neopestalotiopsis* sp., en *Phytophthora cactorum* on/in *Fragaria* seeds by TaqMan real-time PCR. These pathogens are all known to infect the fruit (and other plant parts) of *Fragaria* and more fungi and oomycetes that infect the fruit may be expected on the seeds. The majority of fruit-infecting species listed by Garrido et al. (2011) are also widespread in the EU and other parts of the world (Table 1). From the (groups of) fungi and oomycetes listed in Table 1, *C. fragariae* is the only species that is not known to be present in the EU. Many species that can infect *Fragaria* including species that affect the strawberry fruit are known to be seed-borne (and seed-transmitted) in other plant species (Table 2).

There are more fungi and oomycetes that can affect *Fragaria* fruit than those listed by Garrido et al. (2011), e.g. *Pilidium lythri* (previously named *P. concavum*) and *Neurospora dictyophora* (Lopes et al., 2010; Debode et al., 2011; Rivera et al., 2024). Under specific conditions, especially the fleshy fruit of *Fragaria* may be susceptible to various kinds of fungi, including species that are generally not known as plant pathogens. For example, Rivera et al. (2024) attributed fruit infections of *N. dictyophora* to poor ventilation and high temperatures in greenhouses in Mexico. Such organisms may also be associated with the seeds, but seed transmission seems unlikely for organisms that are only known to colonize the fruit and no other plant tissues. Fungi and oomycetes that are present on the fruit may be removed by disinfection of the seeds prior to sowing (Miller et al., 1992; El Hamdouni et al., 2001; Galvão et al., 2014).

Table 1. Fungi and oomycetes that cause fruit diseases in *Fragaria*: pest status in the EU according to (CABI, 2025) unless stated otherwise.

Species	**Pest status in the EU (and other parts of the world)**
Alternaria tenuissima	Reported in 5 EU member states; cosmopolitan (CABI, 2021h)
Aspergillus niger	Widespread in the EU (≥ 10 EU member states), cosmopolitan,
Athelia rolfsii	Widespread in the EU, cosmopolitan
Botrytis cinerea	Widespread in the EU, cosmopolitan
Colletotrichum acutatum sensu lato	Widespread in the EU, cosmopolitan
Colletotrichum fragariae	Not reported in the EU
Colletotrichum spp. other than *C. acutatum sensu lato* and *C. fragariae*	Cosmopolitan (Rose & Damm, 2024)
Coniella straminea	Cosmopolitan (Alvarez et al., 2016)
Gnomoniopsis comari	EU: Finland, Germany (MycoBank, 2025) Outside the EU: Switzerland (MycoBank, 2025)
Mucor spp.	*Mucor* spp. in general cause fruit rot, are cosmopolitan and are widespread in the EU
Penicillium spp.	*Penicillium* spp. in general cause fruit rot, are cosmopolitan and are widespread in the EU
Pestalotiopsis longisetula	Cosmopolitan (Van Hemelrijck et al., 2016; EPPO, 2021)

Species	Pest status in the EU (and other parts of the world)
Phytophthora cactorum	Widespread in the EU, cosmopolitan
Phytophthora citrophthora	Widespread in the EU, cosmopolitan
Phytophthora nicotianae var. *nicotianae*	Cosmopolitan (Waterhouse & Waterston, 1964)
Ramularia grevilleana	EU: Ireland, Poland (CABI, 2019), Germany (Richter & Jage, 2003) Outside the EU: India, Japan, United States (CABI, 2019), Iran (Heydari et al., 2017)
Rhizoctonia fragariae	EU: Italy, Spain Outside the EU: Egypt and the United States
Rhizoctonia solani	Cosmopolitan (Akber et al., 2023)
Rhizopus sexualis	Reported from Japan and United Kingdom (Lunn, 1977) but may have a wider distribution because *Rhizopus* species are generally considered cosmopolitan
Rhizopus stolonifer	Cosmopolitan
Sclerotinia sclerotiorum	Widespread in the EU, cosmopolitan
Stagonospora fragariae	Litte information found: records in Europe in France (Fungorum, 2025) and Scotland (United Kingdom) (NBNAtlas, 2025)

Table 2. Seed transmission (ST) of plant pathogenic fungi and oomycetes of *Fragaria* found to be seedborne in other plant species (T = shown to be transmitted through seeds including indirect transmission via the environment, TI = transmission found after inoculation of seeds (transmission uncertain under natural conditions), NE = no evidence found for seed transmission).

Fungus/oomycete	Plant species[1]	ST	References
Alternaria alternata	Various plant species	T	(Kgatle et al., 2018; CABI, 2021a)
Alternaria tenuissima	*Triticum aestivum* (wheat)	TI	(Perello & Larran, 2013)
Aspergillus niger	*Allium cepa* (onion)	T	(Hayden & Maude, 1992)
Athelia rolfsii	Various plant species	NE	(CABI, 2021b)
Boeremia lycopersici	*Solanum lycopersicum* (tomato)	T	(Phillips, 1956; Derbyshire, 1960)
Botrytis cinerea	*Cicer arietinum* (chickpea)	T	(Burgess et al., 1997)
Cladosporium spp.	*Phaseolus vulgaris* (bean), *Spinacia oleracea* (spinach)	T	(Hernandez-Perez, 2005; Guimarães et al., 2014)
Colletotrichum spp.	*Capsicum annuum* (pepper), *Phaseolus vulgaris* (bean)	T	(Tu, 1983; Lee, 1995; El-Ammari et al., 1997)
Fusarium oxysporum	Various plant species	T	(Bassi & Goode, 1978; Collins, 2016; Petkar & Ji, 2017)
Fusarium sambucinum	*Allium cepa* (onion)	T	(Koycu & Ozer, 1997)
Macrophomina phaseolina	*Phaseolus vulgaris* (common bean)	T	(Parsa et al., 2016)

Fungus/oomycete	Plant species[1]	ST	References
Mucor spp.	*Vigna unguiculata* (cowpea)	NE	(Pachoute et al., 2024)
Paraconiothyrium fuckelii	*Capsicum frutescens* (chili pepper)	NE	(Chigoziri & Ekefan, 2013)
Penicillium spp.	*Zea mays* (maize)	T	(CABI, 2021i)
Phytophthora cactorum	*Carthamus tinctorius*	NE	(Zad, 1992)
Phytophthora citrophthora	*Citrus*	T	(CABI, 2021g)
Phytophthora cryptogea	*Cichorium* (chicory), *Spinacia oleracea* (spinach)	NE	(Gullino et al., 2012)[2]
Phytophthora megasperma	*Pisum sativum* (pea)	NE	(Ozgonen & Gulcu, 2011)
Phytophthora nicotianae var. *nicotianae*	*Capsicum annuum* (sweet pepper)	NE	(Bhardwaj et al., 1987)
Pythium ultimum	*Pisum sativum* (pea)	NE	(El-Nagerabi et al., 2000)
Rhizoctonia solani	*Gossypium hirsitum* (Cotton)	TI	(Khatun et al., 2023)
Rhizopus stolonifer	*Zea mays* (maize)	T	(dos Santos e Silva et al., 2019; CABI, 2021c)
Sclerotinia sclerotiorum	Various species	T[3]	(Saharan & Mehta, 2008)
Verticillium alboatrum sensu lato	*Medicago sativa* (alfalfa)	T	(Christen, 1982; Gilbert & Peaden, 1988)
Verticillium dahliae	*Helianthus annuus* (sunflower)	T	(Sackston & Martens, 1959)

[1] The species may be seed-borne (and seed-transmitted) in additional host plants, but no full literature search was performed to identify all host plants.
[2] No details were provided how *P. cryptogea* was confirmed to be present on the seeds of chicory and spinach.
[3] Generally considered to be seed-transmitted in various crops but no experimental evidence found through naturally infected seeds.

3.4 Nematodes

Plant-parasitic nematodes that affect above-ground plant parts of *Fragaria* (*Ditylenchus dipsaci* and various *Aphelenchoides* spp.) are seed-borne and seed-transmitted in various plant species, but they are not known to be seed-borne in *Fragaria* (Table 3). In addition to the *Aphelenchoides* species listed in Table 3, *A. smolae* has been found associated with *Fragaria* (Subbotin, 2024). However, it is not known whether this species actually causes any disease in *Fragaria* or other plant species.

According to Pscheidt & Ocamb (2025), *D. dipsaci* is rarely found in strawberry fruit. In addition, the seeds of *Fragaria* may be too small to carry *Ditylenchus dipsaci*. The seeds of *Fragaria* that are measure approximately 1.3 mm (examples of sizes in PlantAtlas (2025) are: *Fragaria x ananassa* length 1.3 and width 1.1 mm, *F. mosschata* length 1.3 and width 1 mm, *F. vesca* length 1.3 and width 0.9 mm), while J4-juveniles of *D. dipsaci* (the survival stage in dry seeds) are approximately 1.0 mm long (Esquibet et al., 1998). For these reasons, seed transmission of *D. dipsaci* in *Fragaria* seems unlikely.

Aphelenchoides species are generally smaller than *D. dipsaci* which makes their presence in small seeds more likely. However, *Aphelenchoides* species are known to feed on leaves and buds of *Fragaria,* but fruit of *Fragaria* is not known to carry the nematodes (FAO, 2016; CABI, 2022; Bozbuga et al., 2023). Therefore, association of *Aphelenchoides* spp. with *Fragaria* seeds seems unlikely.

Table 3. Plant-parasitic nematodes of *Fragaria* known to be seed-transmitted in plant species other than *Fragaria*

Nematode	**Host plants[1]**	**Reference**
Aphelenchoides besseyi	*Oryza sativa* (rice)	(EPPO, 2015)
Aphelenchoides blastophthorus	*Callistephus chinensis*	(Burckhardt, 1972)
Aphelenchoides fragariae[2]	Forage grasses	(Favoreto et al., 2011)
Aphelenchoides ritzemabosi	*Aster* (aster), *Callistephus chinensis*, *Salvia splendens* (scarlet sage)	(Burckhardt, 1972; Chalanska et al., 2011; Blancard, 2014)
Ditylenchus dipsaci	*Allium* spp., *Beta vulgaris* (beet), *Cucumis melo* (melon), *Dipsacus* spp. (teasel), *Medicago sativa* (lucerne/alfalfa), *Pisum sativum* (pea), *Vicia* spp.	(Caubel, 1983; Hajihassani et al., 2016; Kumar & Gupta, 2020)

[1] The listed host plants are examples and no full literature search was performed to identify all host plants in which the pest is known to be seed-borne.
[2] No experimental evidence found, but because of biological similarities with the other *Aphelenchoides* spp. considered to be transmitted by seeds.

3.5 Viruses and viroids

Fourty-three viruses and viroids were identified that have been reported to infect *Fragaria* (Annex A). Two of the viruses are now considered phantom agents. For three viruses, confirmation is needed that *Fragaria* is a true (natural) host plant. This includes raspberry bushy dwarf virus (RBDV, *Idaeovirus rubi*), for which seed transmission has been shown after experimental inoculation of plants (Annex B). However, because there is no conclusive evidence that *Fragaria* is a natural host, RBDV was not included in the list of viruses with evidence for seed transmission in *Fragaria*. *Fragaria* was, however, considered a natural host of the remaining 38 viruses and viroids. For five out of these 38 viruses and viroids (Arabis mosaic virus, beet ringspot virus, Fragaria chiloensis latent virus, raspberry ringspot virus, strawberry necrotic shock virus), evidence was found that they are seed-transmitted in *Fragaria* (Table 4, Annex B). For two other viruses (Fragaria chiloensis cryptic virus, tomato ringspot virus), the current evidence was considered limited or inconclusive (Table 5, Annex B). The EU regulatory status of these seven viruses is discussed in section 3.5.1. This section also discusses the need of a pest categorisation of the non-regulated viruses. Section 3.5.2 lists the viruses and viroids for which no evidence was found for seed transmission in *Fragaria* but for which evidence was found in other plant species.

3.5.1 Regulatory status of viruses with (inconclusive or limited) evidence for seed transmission

Arabis mosaic virus and raspberry ringspot virus are RNQPs in the EU for plants for planting of *Fragaria* (including seeds) (Table 4).

Beet ringspot virus (BRSV), Fragaria chiloensis latent virus (FCiLV) and Fragaria chiloensis cryptic virus (FClCV) are not regulated in the EU (Tables 4,5):

- BRSV has a broad host range including potato, sugar beet, turnip, many ornamental species and weeds (Harrison, 1957; Kis et al., 2017; Jordan et al., 2019; Motsar et al., 2025). In the Netherlands, BRSV has been detected in plants of *Cucurbita pepo* (pers. comm. NVWA-NIVIP, October 2025). BRSV was formerly considered a strain of tomato black ring virus (TBRV), a virus that is an RNQP for plants for planting other than seeds of *Fragaria, Prunus avium, Prunus cerasus* and *Rubus* (Implementing Regulation (EU) 2019/2072, Annex IV, Part J). BRSV has been present in Europe for many decades but there is little information about its distribution in the EU (Fowkes et al., 2022). In the EU, BRSV has been isolated from plants in at least three EU member states (Germany, Hungary and the Netherlands) (Fowkes et al., 2022; Jones et al., 2022; Motsar et al., 2025). Presumably, it has a wider distribution because of its long history of presence in Europe and its broad host range. In the past, isolates that have been identified as TBRV may actually have been BRSV. In view of the above, BuRO does not consider this virus to fulfil the criteria of a Union quarantine pest and no pest categorisation was made[3].
- FCiLV and FClCV: EFSA Panel on Plant Health et al. (2019a) conducted a pest categorisation for FCiLV and FClCV and concluded that these viruses do not qualify for a Union quarantine status because no economic impact was expected if the viruses were to become established in the EU. BuRO agrees with this conclusion.

Tomato ringspot virus (ToRSV)) is an RNQP in the EU for plants for planting other than pollen and seeds of *Malus*, *Prunus* and *Vaccinium* and plants for planting other than pollen of *Rubus* but is not regulated for *Fragaria* (Implementing Regulation (EU) 2019/2072, Annex IV, Part J; Table 5).

Strawberry necrotic shock virus, is an EU-Q and is (by definition) regulated for all plants for planting (Table 4). Special requirements are in place for plants for planting of *Cydonia, Fragaria, Malus, Prunus, Pyrus, Ribes* and *Rubus* to reduce the risk of SNSV but seeds are exempted from these requirements (Annex VII of Implementing Regulation (EU) 2019/2072, point 45).

Table 4. Regulatory status of viruses with evidence for seed transmission in *Fragaria* (see Annex B for details and references)

Virus	**Binomial name**	**Regulatory status**	**Regulated for plants for planting other than seeds of *Fragaria*?**	**Regulated for seeds of *Fragaria*?**
Arabis mosaic virus	*Nepovirus arabis*	RNQP	Yes	Yes
Beet ringspot virus	*Nepovirus betae*	Not regulated	No	No
Fragaria chiloensis latent virus	*Ilarvirus FCILV*	Not regulated	No	No
Raspberry ringspot virus	*Nepovirus rubri*	RNQP	Yes	Yes
Strawberry necrotic shock virus	*Ilarvirus SNSV*	EU-Q	Yes	Yes (but seeds are exempted from the special requirements)[1]

[1] Special requirements in Annex VII of Implementing Regulation (EU) 2019/2072, point 45

[3] One of the criteria of an EU-Q is that the pest is not present in the EU or, if present, is not widely distributed (Articles 3-4 in Regulation (EU) 2016/2031 of 23.11.2016, OJ 317, 4-104).

Table 5. Regulatory status of viruses with limited or inconclusive evidence for seed transmission in *Fragaria* (see Annex B for details and references)

Virus	Binomial name	Regulatory status	Regulated for plants for planting of Fragaria?	Regulated for seeds of Fragaria?
Fragaria chiloensis cryptic virus	-	Not regulated	No	No
Tomato ringspot virus	*Nepovirus lycopersici*	RNQP	No	No

3.5.2 Viruses with evidence for seed transmission in other plant species

Three viruses (apple mosaic virus, tobacco streak virus and tomato black ring virus) have been listed as being seed-transmitted in a review of strawberry viruses (Tzanetakis & Martin, 2013). However, no supporting evidence of seed transmission in *Fragaria* was found for these viruses. For these three viruses, another four viruses and one viroid, evidence for seed transmission was found in other host plants (Table 6, Annex B).

Table 6. Viruses with no evidence of seed transmission in *Fragaria* but evidence of seed transmission in other host plants (see Annex B for details and references)

Virus/viroid	Binomial name	Host plants with evidence of seed transmission[1]
Apple mosaic virus	*Ilarvirus ApMV*	*Corylus avellana* (hazelnut)
Cucumber mosaic virus	*Cucumovirus CMV*	*Capsicum annuum* (pepper), *Spinacia oleraceae* (spinach), *Vigna unguiculata* (cowpea)
Hop stunt viroid	*Hostuviroid impedihumuli*	*Vitis vinifera* (grape), *Prunus domestica* (plum)
Olive latent virus 1	*Alphanecrovirus oleae*	*Olea europaea* (olive)
Spinach latent virus	*Ilarvirus SLV*	*Chenopodium quinoa* (quinoa), *Nicotiana clevelandii* (Cleveland's tobacco) and *Spinacia oleracea* (spinach)
Strawberry latent ringspot virus	*Stralarivirus fragariae*	*Chenopodium quinoa* (quinoa), *Petroselinum crispum* (parsley), *Stellaria media* (common chickweed)
Tobacco streak virus	*Ilarvirus TSV*	*Glycine max* (soja), *Phaseolus vulgaris* (common bean), *Verbesina encelioides* (American dogweed), *Vigna angularis* (red mung bean)
Tomato black ring virus	*Nepovirus nigranuli*	*Lactuca sativa* (lettuce), *Sambucus nigra* (elder)

[1] The virus or viroid may be seed-transmitted in more host plants, but no full literature search was done to identify all host plants in which the pest has been found to be seed-transmitted.

4 Discussion and conclusions

Evidence of seed transmission in *Fragaria* was found for five viruses:

- Arabis mosaic virus (ArMV, *Nepovirus arabis*),
- beet ringspot virus (BRSV, *Nepovirus betae*),
- Fragaria chiloensis latent virus (FCiLV, *Ilarvirus FCILV*),
- raspberry ringspot virus (RRV, *Nepovirus rubri*),
- strawberry necrotic shock virus (SNSV, *Ilarvirus SNSV*).

In addition, limited or inconclusive evidence of seed transmission in *Fragaria* was found for two other viruses:

- Fragaria chiloensis cryptic virus (FClCV)
- tomato ringspot virus (ToRSV, *Nepovirus lycopersici*)

ArMV and RRV are RNQPs. Both viruses are regulated for seeds of *Fragaria* (and other plants for planting).

BRSV, FCiLV and FClCV are not regulated in the EU. BRSV does not qualify for a Union quarantine status because it is already present in the EU where it is presumably quite common (i.e. does not have a limited distribution). BRSV may qualify for an RNQP status, but testing against RNQP-criteria was not within the scope of the present assessment. FCiLV and FClCV do not qualify for a Union quarantine status because no economic impact is expected if these viruses would become established in the EU.

SNSV has a Union quarantine status and special requirements are in place for plants for planting of *Fragaria*. Seeds are currently exempted from these requirements. ToRSV is an RNQP but not for plants for planting (including seeds) of *Fragaria*.

For seven additional viruses that are known to naturally infect *Fragaria*, evidence was found for seed transmission in other hosts than *Fragaria*, while evidence is lacking for seed transmission in *Fragaria.* Three of these viruses (apple mosaic virus, tobacco streak virus and tomato black ring virus) have been listed as being seed-transmitted in *Fragaria* by Tzanetakis & Martin (2013) but without reference to original experimental evidence. It should, however, be taken into account that more viruses may be seed-transmitted in *Fragaria* than those for which experimental evidence was found in the present assessment. This may especially be the case for viruses that belong to the genera *Nepovirus* and *Ilarvirus* including apple mosaic virus, tobacco streak virus and tomato black ring virus. Seed transmission of nepoviruses is very common in herbaceous hosts (ICTV, 2026c) and many carlaviruses are also known to be seed-transmitted (Tables 4,6).

No evidence of seed transmission in *Fragaria* was found for plant-parasitic nematodes. Several plant-parasitic nematodes of *Fragaria* were identified as being seed-transmitted in other plant species. However, seed transmission of these nematodes in *Fragaria* seems unlikely because they are rarely present on the fruit and for some nematodes the seeds may be too small.

Evidence of seed transmission in *Fragaria* was neither found for bacterial or fungal pathogens. A few fungal species that colonize fruits of *Fragaria* have been reported from *Fragaria* seeds, but are only known as seed-borne. Many other fungi and oomycetes and the bacterium *E. pyrifoliae* can also colonize the fruits of *Fragaria*. These pathogens may, therefore, also be seed-borne.

Propagation of strawberries by seed is becoming increasingly important. So far, cultivated *Fragaria* plants have mainly been propagated vegetatively. Consequently, there is limited experience with transmission of pathogens through *Fragaria* seeds. Additional pathogens may thus be identified as seed-transmitted in *Fragaria* over time, partly because several of the pathogens of *Fragaria* have been identified as seed-transmitted in other plant species.

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Annex A List of organisms included in the assessment

Bacteria

Current scientific name (1. EPPO Global Database, 2. LPSN)	**Name organism in publication or legislation**	**EPPO code**	**Source**
Candidatus Phlomobacter fragariae	Candidatus Phlomobacter fragariae	PHMBFR	(Zreik et al., 1998)
Enterobacter mori	*Enterobacter mori*	ENTBMO	(Ji et al., 2023)
Erwinia amylovora	*Erwinia amylovora*	ERWIAM	(Öztürk & Soylu, 2022)
Erwinia pyrifoliae	*Erwinia pyrifoliae*	ERWIPY	(Wenneker et al., 2017)
Pantoea ananatis	*Pantoea ananatis*	ERWIAN	(Song et al., 2023)
Pseudomonas fragariae	*Pseudomonas fragariae*	-	(Marin et al., 2024)
Ralstonia pseudosolanacearum	*Ralstonia pseudosolanacearum*	RALSPS	(Lowe-Power, 2025)
Rhodococcus fascians	*Rhodococcus fascians* (*Corynebacterium fascians* in publication)	CORBFA	(Bradbury, 1967)
Xanthomonas arboricola pv. fragariae	*Xanthomonas arboricola pv. fragariae*	XANTAF	(Ferrante & Scortichini, 2018)
Xanthomonas fragariae	*Xanthomonas fragariae*	XANTFR	(Roberts et al., 1996)
Xylella fastidiosa	*Xylella fastidiosa*	XYLEFA	(Bradbury, 1991)

Fungi and oomycetes

(source: Garrido et al. (2016) unless stated otherwise)

Current scientific name (1. EPPO Global Database, 2. Mycobank)	**Name organism in publication or legislation**	**EPPO code**
Alternaria alternata	*Alternaria alternata*	ALTEAL
Alternaria tenuissima	*Alternaria tenuissima*	ALTETE
Armillaria mellea	*Armillaria mellea*	ARMIME
Aspergillus niger	*Aspergillus niger*	ASPENI
Athelia rolfsii	*Sclerotium rolfsii*	SCLORO
Boeremia lycopersici	*Phoma lycopersici*	DIDYLY
Botrytis cinerea	*Botrytis cinerea*	BOTRCI
Cercospora fragariae	*Cercospora fragariae*	not available
Cladosporium	*Cladosporium spp.*	1CLADG
Colletotrichum fragariae	*Colletotrichum fragariae*	COLLFR
Colletotrichum acutatum sensu lato[1]	*Colletotrichum acutatum sensu lato*	COLLAC
Colletotrichum spp. other than *C. acutatum sensu lato* and *C. fragariae*	See main text section 3.3	

Current scientific name (1. EPPO Global Database, 2. Mycobank)	**Name organism in publication or legislation**	**EPPO code**
Coniella straminea	*Schizoparme straminea*	SKHZST
Coniothyrium fragariae	*Coniothyrium fragariae*	CONLFR
Cylindrocarpon destructans	*Cylindrocarpon destructans*	NECTRA
Dematophora necatrix	*Rosellinia necatrix*	ROSLNE
Diplocarpon fragariae	*Diplocarpon earlianum*	DIPCEA
Fusarium oxysporum	*Fusarium oxysporum*	FUSAOX
Fusarium sambucinum	*Fusarium sambucinum*	GIBBPU
Gnomoniopsis comari	*Gnomonia comari*	GNMPCO
Identity not clear	*Sphaeropsis malorum*	not available
Idriella lunata	*Idriella lunata*	not available
Macrophomina phaseolina	*Macrophomina phaseolina*	MCPHPH
Mucor hiemalis	*Mucor hiemalis*	MUCOHI
Mucor mucedo	*Mucor mucedo*	MUCOMU
Mucor piriformis	*Mucor piriformis*	MUCOPI
Mycosphaerella louisianae	*Mycosphaerella louisianae*	not available
Not found in the databases	*Sclerotium fragariae*	not available
Olpidium brassicae sensu lato	*Olpidium brassicae*	OLPIBR
Paraconiothyrium fuckelii	*Coniothyrium fuckelii*	LEPTCO
Paraphomopsis obscurans	*Phomopsis obscurans*	PHOPOB
Passalora vexans	*Cercospora vexans*	not available
Penicillium aurantiogriseum	*Penicillium cyclopium*	PENIAU
Penicillium expansum	*Penicillium expansum*	PENIEX
Penicillium glabrum	*Penicillium frequentans*	PENIGB
Penicillium purpurogenum	*Penicillium purpurogenum*	PENIPU
Pestalotiopsis longisetula	*Pestalotia longisetula*	PESTLO
Phytophthora bisheria	*Phytophthora bisheria*	PHYTBS
Phytophthora cactorum	*Phytophthora cactorum*	PHYTCC
Phytophthora citricola	*Phytophthora citricola*	PHYTCI
Phytophthora citrophthora	*Phytophthora citrophthora*	PHYTCO
Phytophthora cryptogea	*Phytophthora cryptogea*	PHYTCR
Phytophthora fragariae	*Phytophthora fragariae*	PHYTFR
Phytophthora megasperma	*Phytophthora megasperma*	PHYTME
Phytophthora nicotianae var. nicotianae	*Phytophthora nicotianae*	PHYTNN
Pilidium lythri	*Hainesia lythri*	DISHOE
Podosphaera aphanis[1]	*Podosphaera aphanis*	PODOAP
Pythium ultimum	*Pythium ultimum*	PYTHUL

Current scientific name (1. EPPO Global Database, 2. Mycobank)	Name organism in publication or legislation	EPPO code
Ramularia grevilleana	*Mycosphaerella fragariae*	MYCOFR
Rhizoctonia fragariae	*Rhizoctonia fragariae*	RHIZFR
Rhizoctonia solani	*Rhizoctonia solani*	RHIZSO
Rhizopus sexualis	*Rhizopus sexualis*	RIZPSE
Rhizopus stolonifer	*Rhizopus stolonifer*	RIZPST
Sclerotinia sclerotiorum	*Sclerotinia sclerotiorum*	SCLESC
Septoria aciculosa	*Septoria aciculosa*	not available
Septoria fragariae	*Septoria fragariae*	SEPTFR
Septoria fragariaecola	*Septoria fragariaecola*	not available
Setophoma terrestris	*Phoma terrestris*	PYRETE
Stagonospora fragariae	*Stagonospora fragariae*	STAGFR
Verticillium alboatrum sensu lato	*Verticillium albo-atrum*	VERTAA
Verticillium dahliae	*Verticillium dahliae*	VERTDA

[1] Source: see main text section 3.3

Viruses and viroids

Name in publication (acronym)	Binomial name	EPPO code	Source
Apple mosaic virus (ApMV)	*Ilarvirus ApMV*	APMV00	(EFSA Panel on Plant Health et al., 2019b)
Apple rootstock virus A (ApRVA)	-	not available	(Villamor et al., 2022)
Arabis mosaic virus (ArMV)	*Nepovirus arabis*	ARMV00	(EFSA Panel on Plant Health et al., 2019b)
Beet pseudoyellows virus (BPYV)	*Crinivirus pseudobetae*	BPYV00	(EFSA Panel on Plant Health et al., 2019b)
Beet ringspot virus (BRSV)	*Nepovirus betae*	BRSV00	(Lister & Murant, 1967; Fowkes et al., 2022)
Crassocephalum yellow vein virus (CraYVV)	*Begomovirus crassocephali*	CRAYVV	(Zhao et al., 2020)
Cucumber mosaic virus (CMV)	*Cucumovirus CMV*	CMV000	(EFSA Panel on Plant Health et al., 2019b)
Fragaria chiloensis cryptic virus (FCCV)	-	FCLCV0	(EFSA Panel on Plant Health et al., 2019b)
Fragaria chiloensis latent virus (FCiLV)	*Ilarvirus FCILV*	FCILV0	(EFSA Panel on Plant Health et al., 2019b)
Fragaria vesca-associated virus 1 (FVaV-1)[1]	-	not available	(Lenz et al., 2020)

Name in publication (acronym)	Binomial name	EPPO code	Source
Hop stunt viroid (HSVd)	*Hostuviroid impedihumuli*	HSVD00	(EFSA Panel on Plant Health et al., 2019b)
Lycopersicon esculentum nepovirus (LENV)	-	not available	(Huang et al., 2021)
Olive latent virus 1	*Alphanecrovirus oleae*	OLV100	(Fránová et al., 2019)
Plum bark necrosis stem pitting-associated virus (PBNSPaV)	*Ampelovirus pruni*	PBNSPA	(EFSA Panel on Plant Health et al., 2019b)
Raspberry bushy dwarf virus (RBDV)[2]	*Idaeovirus rubi*	RBDV00	(Davalos et al., 2021)
Raspberry ringspot virus (RpRSV)	*Nepovirus rubi*	RPRSV0	(EFSA Panel on Plant Health et al., 2019b)
Spinach latent virus (SpLV)	*Ilarvirus SLV*	SPLV00	(Huang et al., 2021)
Strawberry chlorotic fleck-associated virus (SCFaV)	*Closterovirus fragariae*	SCFAV0	(EFSA Panel on Plant Health et al., 2019b)
Strawberry crinivirus 3 (SCrV-3)	-	not available	(EFSA Panel on Plant Health et al., 2019b)
Strawberry crinivirus 4 (SCrV-4)	-	not available	(EFSA Panel on Plant Health et al., 2019b)
Strawberry crinkle virus (SCV)	*Alphacytorhabdovirus fragariarugosus*	SCRV00	(EFSA Panel on Plant Health et al., 2019b)
Strawberry Kurdistan virus (SKV)	-	not available	(Hajizadeh et al., 2025)
Strawberry latent C virus (SLCV)[3]	-	STLCV0	(EFSA Panel on Plant Health et al., 2019b)
Strawberry latent ringspot virus (SLRSV)	*Stralarivirus fragariae*	SLRSV0	(EFSA Panel on Plant Health et al., 2019b)
Strawberry latent virus (StLV)[4]	-	not available	(EFSA Panel on Plant Health et al., 2019b)
Strawberry leaf curl virus (StLCV)[3]	-	STWLCV	(EFSA Panel on Plant Health et al., 2019b)
Strawberry mild yellow edge virus (SMYEV)	*Potexvirus fragariae*	SMYEV0	(EFSA Panel on Plant Health et al., 2019b)
Strawberry mottle virus (SMoV)	*Sadwavirus fragariae*	SMOV00	(EFSA Panel on Plant Health et al., 2019b)
Strawberry necrotic shock virus (SNSV)	*Ilarvirus SNSV*	SNSV00	(EFSA Panel on Plant Health et al., 2019b)

Name in publication (acronym)	Binomial name	EPPO code	Source
Strawberry pallidosis-associated virus (SPaV)	*Crinivirus palidofragariae*	SPAV00	(EFSA Panel on Plant Health et al., 2019b)
Strawberry polerovirus 1 (SPV-1)	*Polerovirus SPV*	SPV100	(EFSA Panel on Plant Health et al., 2019b)
Strawberry pseudo mild yellow edge virus (SPMYEV)	*Carlavirus fragariae*	SPMYEV	(EFSA Panel on Plant Health et al., 2019b)
Strawberry vein banding virus (SVBV)	*Caulimovirus venafragariae*	SVBV00	(EFSA Panel on Plant Health et al., 2019b)
Strawberry virus 1 (StrV-1)/Strawberry-associated virus 1 (SaV1)	*Alphacytorhabdovirus alphafragariae*	not available	(Ding et al., 2019; Fránová et al., 2019)
Strawberry virus 2 (StrV-2)	*Alphacytorhabdovirus betafragariae*	not available	(Medberry & Tzanetakis, 2022)
Strawberry virus 3 (StrV-3)	*Deltanucleorhabdovirus fragariae*	not available	(Medberry et al., 2023)
Strawberry virus A (StraVA)	-	not available	(Koloniuk et al., 2022)
Tobacco necrosis virus A (TNVA)[5]	*Alphanecrovirus nicotianae*	TNV000	(EFSA Panel on Plant Health et al., 2019b)
Tobacco necrosis virus D (TNVD)[5]	*Betanecrovirus nicotianae*	TNV000	(Fránová-Honetšlegrová et al., 1998; Fránová-Honetslegrová et al., 1999)
Tobacco streak virus (TSV)	*Ilarvirus TSV*	TSV000	(EFSA Panel on Plant Health et al., 2019b)
Tomato black ring virus (TBRV)	*Nepovirus nigranuli*	TBRV00	(EFSA Panel on Plant Health et al., 2019b)
Tomato ringspot virus (ToRSV)	*Nepovirus lycopersici*	TORSV0	(EFSA Panel on Plant Health et al., 2019b)
Turnip yellows virus (TuYV)[6]	*Polerovirus TUYV*	TUYV00	(He et al., 2022)

[1] Questionable finding, this virus may have been sequenced from an insect

[2] Davalos et al. (2021) reported detection of RBDV by dot-immunobinding assay in strawberry crops in the United States. Presence of the virus was not confirmed by other methods. RBDV is a common virus of *Rubus* worldwide and is spread by pollen (Martin, 2001). Therefore, it cannot not be ruled out that the positive detection results were caused by the presence of infected *Rubus*-pollen on the strawberry plants and the status of *Fragaria* as a natural host of RBDV still needs confirmation.

[3] SLCV and StLCV are currently considered to be phantom agents (Tzanetakis et al., 2024).

[4] Virus poorly characterized (EFSA Panel on Plant Health et al., 2019b).

[5] TNVA and TNVD have been elevated from the rank of strains of tobacco necrosis virus (TNV) to the rank of species and placed in two separate genera (Pringle, 1998). Both species were included as TNV in the pest list compiled by the EFSA Panel on Plant Health et al. (2019b). Older publications that refer to the presence of TNV in strawberry do not always distinguish between the two strains, creating uncertainty about which of the current species is involved. TNVD has since been isolated from asymptomatic plants of *Fragaria* x *ananassa* (Fránová-Honetšlegrová et al., 1998; Fránová-Honetslegrová et al., 1999), while there is no definitive prove of the host plant status of *Fragaria* for TNVA.

[6] Reported as Brassica yellows virus (BrYV) in *Fragaria* by He et al., 2022). However, BrYV is considered an isolate of turnip yellows virus (TuYV, *Polerovirus TUYV*) according to ICTV (2025a).

Annex B Seed transmission of viruses and viroids in *Fragaria* and other hosts

Virus (acronym)	**Conclusion –** Evidence[1]
Apple mosaic virus (ApMV)	**No evidence of seed transmission in *Fragaria*. Evidence of seed transmission in one other host plant** ApMV is listed as seed-transmitted by Tzanetakis & Martin (2013) in a review of strawberry viruses, but without specification of evidence. No other information was found on seed transmission in *Fragaria*. Results from Cameron & Thompson (1985) and Postman & Mehlenbacher (1992) indicate seed transmission, but no pollen transmission, in hazelnut (*Corylus avellana*). An experimental study in roses showed no evidence of seed transmission (Golino et al., 2005).
Apple rootstock virus A (ApRVA)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. ApRVA belongs to the familiy Rhabdoviridae and members of this family are generally not seed-transmitted (Walker et al., 2026).
Arabis mosaic virus (ArMV)	**Evidence of seed transmission in *Fragaria*** Seed transmission was found through seeds collected from naturally infected plants of two cultivars of *Fragaria* x *ananassa*, from which 11 out of 110 and 2 out of 78 seedlings became infected (Lister and Murant, 1967).
Beet pseudoyellows virus (BPYV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information found on seed transmission. Seed transmission is also not expected. BPYB belongs to the familiy Closteroviridae in which seed transmission is not known (Fuchs et al., 2020).
Beet ringspot virus (BRSV)	**Evidence of seed transmission in *Fragaria*.** Seed transmission is reported in *Fragaria* (Lister & Murant, 1967). The isolate of this study is described as the Scottish isolate of TBRV, isolated from *Arctium lappa.* This isolate was later sequenced and confirmed to be an isolate of BRSV (Fowkes et al., 2022). Seed transmission of this isolate was found through seeds collected from naturally infected plants of two cultivars of *Fragaria* x *ananassa*, from which 26 out of 76 and 2 out of 28 seedlings became infected (Lister & Murant, 1967).
Crassocephalum yellow vein virus (CraYVV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. CraYVV belongs to the family of Geminiviridae that are generally phloem-limited (Möller & Maruthi, 2025) and phloem-limited viruses are generally not seed-transmitted (Mink, 1993).
Cucumber mosaic virus (CMV)	**No evidence of seed transmission in *Fragaria*. Evidence of seed transmission in several other host plants.** No information was found on seed transmission in *Fragaria*.

Virus (acronym)	**Conclusion –** Evidence[1]
	Seed transmission of CMV was (for example) reported in seeds collected from artificially infected *Capsicum annuum* (Ali & Kobayashi, 2010) and *Vigna unguiculata* plants (Abdullahi et al., 2001). Seed and pollen transmission was also found in *Spinacia oleracea* after crossing naturally infected female plants with healthy male plants and vice versa (Yang et al., 1997).
Fragaria chiloensis cryptic virus (FClCV)	**Limited or inconclusive evidence of seed transmission in *Fragaria*** Seed transmission was deduced from the observation that multiple infected *Fragaria chiloensis* plants were clones of seedlings grown from seed, combined with the notion that all cryptic viruses are solely seed and pollen transmitted (Tzanetakis et al., 2008). No information was found on seed transmission in other host species (No other host species are reported).
Fragaria chiloensis latent virus (FCiLV)	**Evidence of seed transmission in *Fragaria*** Seed transmission was found through seeds collected from naturally infected *Fragaria chiloensis* plants (Spiegel et al., 1993), from which 23 out of 42 seedlings became infected.
Fragaria vesca-associated virus 1 (FVaV-1)[2]	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. The genomic organization and sequence of this virus indicated relatedness to members of the proposed insect-specific genus Negevirus (Lenz et al. 2020). Evidence that *Fragaria* is a true natural host plant of this virus is currently lacking.
Hop stunt viroid (HSVd)	**No evidence of seed transmission in *Fragaria*. Evidence of seed transmission in other host plants** No information was found on seed transmission in *Fragaria*. Seed transmission was found in *Vitis vinifera* and *Prunus domestica* ('plum' in the publication) (Wan Chow Wah & Symons, 1999; Luigi et al., 2010).
Lycopersicon esculentum nepovirus (LENV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. However, many other nepoviruses are known to be seed-transmitted (see also Chapter 4 of the main text).
Olive latent virus 1	**No evidence of seed transmission in *Fragaria*. Evidence of seed transmission in one other host plant** Seed transmission has been reported in olive (Saponari et al., 2002).
Plum bark necrosis stem pitting-associated virus (PBNSPaV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. Seed transmission is also not expected. PBNSPaV belongs to the familiy Closteroviridae in which seed transmission is not known (Fuchs et al., 2020).

Virus (acronym)	Conclusion – Evidence[1]
Raspberry bushy dwarf virus (RBDV)[2]	**Evidence of seed transmission in artificially infected *Fragaria* plants but evidence on natural host plant status is inconclusive. Evidence of seed transmission in several other host plants** Seed transmission was found through seeds collected from artificially infected *Fragaria vesca* plants (Murant et al., 1974; Credi et al., 1986). Two infected seedlings were found among 64 tested plants by Murant et al. (1974) and eight out of 99 plants by Credi et al. (1986). These experiments demonstrate that, following artificial infection, the virus is able to cause a systemic infection in *Fragaria,* and infect or contaminate the seeds, which subsequently can result in infected seedlings. However, the status of *Fragaria* as a natural host needs confirmation (see Viruses and viroids in Annex A). Seed transmission has been demonstrated in plant species known as natural hosts, including *Rubus idaeus* (Converse, 1973; Murant et al., 1974) and *Rubus longanobaccus* (Ormerod, 1970).
Raspberry ringspot virus (RpRSV)	**Evidence of seed transmission in *Fragaria*** Seed transmission was found through seeds collected from naturally infected plants of two cultivars of *Fragaria* x *ananassa*, from which 27 out of 55 and 2 out of 24 seedlings became infected (Lister and Murant, 1967).
Spinach latent virus (SpLV)	**No evidence of seed transmission in *Fragaria*. Evidence of seed transmission in several other host plants** No information was found on seed transmission in *Fragaria*. Seed transmission was found in several plant species, including *Chenopodium quinoa*, *Nicotiana clevelandii* (Štefanac & Wrischer, 1983), and *Spinacia oleracea* (Bos et al., 1979;1980).
Strawberry chlorotic fleck-associated virus (SCFaV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. Seed transmission is also not expected. SCFaV belongs to the familiy Closteroviridae in which seed transmission is not known (Fuchs et al., 2020).
Strawberry crinivirus 3 (SCrV-3)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. Criniviruses are not known to be seed-transmitted (ICTV, 2026a).
Strawberry crinivirus 4 (SCrV-4)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. Criniviruses are not known to be seed-transmitted (ICTV, 2026a).
Strawberry crinkle virus (SCV)	**No evidence of seed transmission in *Fragaria* and other host plants** An experimental study in *Fragaria vesca* and *F. grandiflora* showed no evidence of seed transmission (Kacharmazov & Khristov, 1976).

Virus (acronym)	**Conclusion –** Evidence[1]
	No information was found on seed transmission in other host plants. SCV belongs to the Rhabdoviridae and members of this family are generally not seed-transmitted (Walker et al., 2026).
Strawberry Kurdistan virus (SKV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. Seed transmission is also not expected. SKV belongs to the familiy Closteroviridae in which seed transmission is not known (Fuchs et al., 2020).
Strawberry latent C virus (SLCV) Phantom agent[3]	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. ~~Rhabdoviridae are generally not seed-transmitted.~~
Strawberry latent ringspot virus (SLRSV)	**No evidence of seed transmission in *Fragaria*. Evidence of seed transmission in several other host plants** SLRSV is listed as seed-transmitted by Tzanetakis & Martin (2013) in a review of strawberry viruses, but without specification of evidence. No other information was found on seed transmission in *Fragaria*. Seed transmission was found in several other plant species, including *Chenopodium quinoa* (Allen et al., 1970) and *Petroselinum crispum* (Bellardi & Bertaccini, 1992).
Strawberry latent virus (StLV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. The virus is poorly characterized (EFSA Panel on Plant Health et al., 2019b)
Strawberry leaf curl virus (StLCV) Phantom agent[3]	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission.
Strawberry mild yellow edge virus (SMYEV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission.
Strawberry mottle virus (SMoV)	**No evidence of seed transmission in *Fragaria* and other host plants** An experimental study in *Fragaria vesca* and *F. grandiflora* showed no evidence of seed transmission (Kacharmazov and Khristov, 1976). No information was found on seed transmission in other host plants.
Strawberry necrotic shock virus (SNSV)	**Evidence of seed transmission in *Fragaria*** Seed and pollen transmission was found after crossing naturally infected female plants with healthy male plants and vice versa (Johnson et al., 1984). When six crosses of infected female plants and healthy male plants were tested, on average 24% of the seedlings became infected (57 out of 233 seedlings). The disease in the paper by Johnson et al. (1984) is described as

Virus (acronym)	Conclusion – Evidence[1]
	‘necrotic shock disease’ caused by tobacco streak virus (TSV). At that time, SNSV was considered a strain of TSV, but this virus is now considered a distinct species and the causative agent of necrotic shock disease (Tzanetakis et al., 2004b).
Strawberry pallidosis-associated virus (SPaV)	**No evidence of seed transmission in *Fragaria* and other host plants** An experimental study in *Fragaria* showed no evidence of seed transmission (Tzanetakis et al., 2004a). No information was found on seed transmission in other host plants. Seed transmission is also not expected. SPaV belongs to the familiy Closteroviridae in which seed transmission is not known (Fuchs et al., 2020).
Strawberry polerovirus 1 (SPV-1)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. Seed transmission is also not expected. SPV-1 belongs to the genus polerovirus and members of this genus are phloem-limited (Delfosse et al., 2021). Phloem-limited viruses are generally not seed-transmitted (Mink, 1993).
Strawberry pseudo mild yellow edge virus (SPMYEV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission.
Strawberry vein banding virus (SVBV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. Seed transmission of caulimoviruses has not been recorded (ICTV, 2026b).
Strawberry virus 1 (StrV-1)/Strawberry-associated virus 1 (SaV1)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. StrV-1/SaV1 belongs to the Rhabdoviridae and members of this family are generally not seed-transmitted (Walker et al., 2026).
Strawberry virus 2 (StrV-2)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. StrV-2 belongs to the Rhabdoviridae and members of this family are generally not seed-transmitted (Walker et al., 2026).
Strawberry virus 3 (StrV-3)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. StrV-3 belongs to the Rhabdoviridae and members of this family are generally not seed-transmitted (Walker et al., 2026).
Strawberry virus A (StraVA)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission.
Tobacco necrosis virus A (TNVA)[2]	**No evidence of seed transmission in *Fragaria* and other host plants**

Virus (acronym)	**Conclusion –** Evidence[1]
	No information was found on seed transmission. No conclusive evidence that *Fragaria* is a natural host plant (see Annex A).
Tobacco necrosis virus D (TNVD)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission.
Tobacco streak virus (TSV)	**No evidence of seed transmission in *Fragaria*. Evidence of seed transmission in several other host plants** Seed transmission of TSV is reported in *Fragaria* (Johnson et al., 1984), but all references to TSV in *Fragaria* may actually refer to SNSV (Tzanetakis, 2012), which was initially considered a strain of TSV, but was described in 2004 as a separate species (Tzanetakis et al., 2004b). Seed transmission is reported in several other hosts, e.g. *Glycine max* (Golnaraghi et al., 2004), *Phaseolus vulgaris, Vigna angularis* (Kaiser et al., 1991), and *Verbesina encelioides* (Sharman et al., 2015).
Tomato black ring virus (TBRV)	**No evidence of seed transmission in *Fragaria*. Evidence of seed transmission in several other host plants** Seed transmission of TBRV is reported in *Fragaria* (Lister & Murant, 1967), but the isolate of this study is described as the Scottish isolate of TBRV, isolated from *Arctium lappa.* This isolate was later sequenced and confirmed to be an isolate of BRSV (Fowkes et al., 2022). Not other information was found in seed transmission in *Fragaria*. Seed transmission was found in several other hosts, e.g. *Beta vulgaris* (Gibbs & Harrison, 1964; Murant, 1983), *Rubus idaeus* (Lister & Murant, 1967) and *Sambucus nigra* (Schimanski, 1987).
Tomato ringspot virus (ToRSV)	**Limited or inconclusive evidence of seed transmission in *Fragaria*. Evidence of seed transmission in several other host plants** Seed transmission of ToRSV in *Fragaria* is mentioned in several publications (Converse & Stace-Smith, 1987; Converse, 1990; Tzanetakis & Martin, 2013). However, the only experimental study found is from Mellor & Stace-Smith (1963). They found seed transmission of a 'ringspot virus' in *Fragaria vesca* and *F. x ananassa* but the identity of the virus was uncertain. High transmission rates were observed, with 175 out of 300 seedlings being infected. Conflicting results were obtained regarding the identification of the virus, which may have either been ToRSV or tobacco ringspot virus (TRSV). Therefore, the evidence is considered inconclusive although the virus seems most likely ToRSV and not TRSV. *Fragaria vesca* is mentioned as a non-host in TRSV-transmission studies of (McGuire, 1973) and *Fragaria* is not listed as a host of TRSV by both EPPO (2025a) and CABI (2024), which suggest that ToRSV was the virus in the study of Mellor & Stace-Smith (1963). Seed transmission has been found in several other hosts, e.g. *Glycine max* (Golnaraghi et al., 2004), *Rubus idaeus* (Braun &

Virus (acronym)	Conclusion – Evidence[1]
	Keplinger, 1973), and *Taraxacum officinale* (Mountain et al., 1983).
Turnip yellows virus (TuYV)	**No evidence of seed transmission in *Fragaria* and other host plants** No information was found on seed transmission. Belongs to the genus polerovirus and members of this genus are phloem-limited (Delfosse et al., 2021). Phloem-limited viruses are generally not seed-transmitted (Mink, 1993).

[1] Evidence for seed transmission in host plants other than *Fragaria* was only investigated if no evidence for seed transmission in *Fragaria* was found.
[2] Uncertain whether *Fragaria* is a natural host of the virus (see Annex A)
[3] Pathogenic agent named in literature but without evidence of it existence (Tzanetakis et al., 2024)