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Pest categorisation of *Fusarium brachygibbosum*

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Abstract

The EFSA Plant Health Panel performed a pest categorisation of *Fusarium brachygibbosum* Padwick. *F. brachygibbosum* is a well-characterised fungal plant pathogen with opportunistic behaviour, mostly isolated along with other fungal pathogens in symptomatic hosts. It has been reported from Africa, America, Asia and Oceania where it is has been associated with a wide range of symptoms on approximately 25 cultivated and non-cultivated plant species. The pathogen has been reported in Italy in soil/marine sediments and in quinoa (*Chenopodium quinoa*) and durum wheat (*Triticum turgidum* subsp. *durum*) seeds. The pathogen is not included in the EU Commission Implementing Regulation 2019/2072. This pest categorisation focused on a selected range of host plant species on which *F. brachygibbosum* fulfilled Koch's postulates and was formally identified by multilocus gene sequencing analysis. Host plants for planting, seed of host plants and soil and other substrates originating in infested third countries are main pathways for the entry of the pathogen into the EU. There are no reports of interceptions of *F. brachygibbosum* in the EU. Host availability and climate suitability factors occurring in the EU are favourable for the establishment of the pathogen in Member States (MSs). Phytosanitary measures are available to prevent the introduction of the pathogen into the EU. Additional measures are available to mitigate the risk of entry and spread of the pathogen in the EU. Despite the low aggressiveness observed in some reported hosts, it has been shown that, in the areas of its present distribution, the pathogen has a direct impact on certain hosts (e.g. almond, onion, soybean, tobacco) that are also relevant for the EU. The Panel concludes that *F. brachygibbosum* satisfies all the criteria to be regarded as a potential Union quarantine pest. However, high uncertainty remains regarding the distribution of the pathogen in the EU and some uncertainty exists about its potential impact in the EU. Specific surveys and re-evaluation of Fusarium isolates in culture collections could reduce these uncertainties.

Keywords: climate suitability, pest distribution, pest risk, plant health, plant pest, quarantine, emerging pathogens

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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 specific import requirements 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

F. brachygibbosum is one of a number of pests listed in Annex 1D to the Terms of Reference (ToR) (Section 1.1.2) to be subject to pest categorisation to determine whether it fulfils the criteria of a regulated pest for the area of the European Union (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 regulated pest, specific import requirements for relevant host commodities will be identified; for pests already present in the EU additional risk reduction options to inhibit spread will be identified.

2. Data and methodologies

2.1. Data

2.1.1. Literature search

A literature search on *F. brachygibbosum* was conducted at the beginning of the categorisation in the ISI Web of Science bibliographic database and the Google Scholar 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.

2.1.2. 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 2.1.1.

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 was 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 EU, 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 interceptions to TRACES in May 2020.

2.2. Methodologies

The Panel performed the pest categorisation for *F. brachygibbosum*, 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) and No. 21 (FAO, 2004).

The criteria to be considered when categorising a pest as an EU regulated quarantine pest (QP) are given in Regulation (EU) 2016/2031 article 3. 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 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	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 established, 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
Regulatory status (Section 3.3)	If the pest is present in the EU but not widely distributed in the risk assessment area, it should be under official control or expected to be under official control in the near future.
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
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 (Specific import requirements) (Section 3.6)	Are there measures available to prevent the entry into the EU such that the likelihood of introduction becomes mitigated?
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 established, or has it been shown to produce consistent symptoms and/or to be transmissible?

Yes, the identity of the pathogen is well-established; the pathogen has been associated with a wide range of symptoms on various host plant species and it has been shown to be transmissible.

Fusarium brachygibbosum Padwick is a fungus of the family *Nectriaceae*. The genus *Fusarium* includes endophytes, saprobes as well as plant and animal/human pathogens (Summerell, 2019), and represents one of the most important genera of plant pathogenic fungi affecting a wide range of crops worldwide. In addition, some species produce toxic secondary metabolites (mycotoxins) in food products with deleterious effects on livestock and humans (Munkvold, 2017).

Over the last 20 years, the use of multi-gene phylogenetic analysis has deeply changed the taxonomy of the genus *Fusarium* (Geiser et al., 2013; Aoki et al., 2014; O'Donnell et al., 2015; Crous et al., 2021), which presently encompasses 20 genealogically exclusive lineages: *F. sambucinum, F. chlamydosporum* (FCSC)*, F. incarnatum-equiseti* (FIESC)*, F. tricinctum, F. heterosporum, F. fujikuroi, F. nisikadoi, F. oxysporum, F. redolens, F. babinda, F. concolor, F. lateritium, F. buharicum, F. buxicola, F. staphyleae, F. solani, F. decemcellulare, F. albidum, F. dimerum* and *F. ventricosum* species complexes or clades (Geiser et al., 2013) (see Section 3.1.5). *F. brachygibbosum* is a phylogenetically distinct species nested outside the above-mentioned complexes (see Section 3.1.5).

F. brachygibbosum was firstly identified on sorghum (*Sorghum bicolor*) based on its morphology by Padwick (1945). Later, it was reported as the causal agent of leaf spot on oleander (*Nerium oleander*) in Iran (Mirhosseini et al., 2014), and associated with root rot in date palm (*Phoenix dactylifera*) in Oman (Al-Sadi et al., 2012). Since then, *F. brachygibbosum* has been associated with different symptoms, including root and tuber rot, crown rot, stalk rot, head blight, ear rot, cankers, wilting, leaf spot, decline and dieback on a wide range of woody and herbaceous hosts, often in association with other fungal species (see Section 3.1.2 'Biology of the pest').

CABI Crop Protection Compendium (CABI, 2021) provides the following taxonomic identification for *F. brachygibbosum*:

Preferred scientific name: *Fusarium brachygibbosum* Padwick (1945)
Order: Hypocreales
Family: Nectriaceae
Genus: *Fusarium*
Species: *Fusarium brachygibbosum* (FUSABC)
Common names: None.
Synonyms: None.

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

3.1.2. Biology of the pest

F. brachygibbosum is a soil-borne filamentous fungus and a plant pathogen with opportunistic behaviour, characterised by a broad distribution worldwide. This fungus may remain cryptic and asymptomatic within the host and induce symptoms once plants are exposed to physiological stress. Nonetheless, asymptomatic, infected nursery plant material may result in the development of the disease and high losses in production in the field (Marek et al., 2013; Punja et al., 2018).

While no disease cycle has been reported specifically for *F. brachygibbosum*, it is likely similar to that of other *Fusarium* species causing canker, rot and wilt diseases. In general, these *Fusarium* species can exist saprophytically, but may also act as opportunistic pathogens. On plant hosts that are predisposed by stress, e.g. cold storage or infection by other pathogens, symptoms may become severe. *F. brachygibbosum* overwinters as mycelium or spores in infected plant debris (including crop residues) and seed, or as chlamydospores (thick-walled asexual spores) and sclerotia in soil (Padwick, 1945; Chitambar, 2016; Stack et al., 2017). Asexual spores (microconidia and macroconidia) are dispersed by wind or rain-splash. Other means of transmission include infected plants, roots, stems, leaves, seeds (Van Coller et al., 2016), plant debris, contaminated soil and equipment. No sexual stage is known for *F. brachygibbosum*.

Besides being a common soil inhabitant (Balmas et al., 2010; Seidle, 2016; González-Delgado et al., 2017; Mojela, 2017; Panelli et al., 2017), *F. brachygibbosum* is associated with symptoms of:

- crown and root rot, or tuber rot (Tan et al., 2011; Al-Sadi et al., 2012; Saleh et al., 2017; Zimudzi et al., 2017; Cao et al., 2018; Punja et al., 2018; Le et al., 2020; Özer et al., 2020; Azil et al., 2021; Ezrari et al., 2021; Mohammed-Ameen et al., 2021; Qiu et al., 2021; Tirado-Ramirez et al., 2021; Wang et al., 2021);
- stalk rot (Shan et al., 2017);
- ear rot (van Coller et al., 2013; Fallahi et al., 2019);
- cankers (Seidle, 2016; Stack et al., 2017);
- wilting (Rentería-Martínez et al., 2015; Trabelsi et al., 2017; Mariscal-Amaro et al., 2017; Punja et al., 2018; Xia et al., 2018; Ali et al., 2020; Azil et al., 2021; Khamas et al., 2021; Rabaaoui et al., 2021);
- leaf spot or leaf wilt (Mirhosseini et al., 2014; Saleh et al., 2017; Al-Nadabi et al., 2020; Namsi et al., 2020);
- decline (Akgül and Ahioğlu, 2019);
- dieback (Al-Mahmooli et al., 2013);

and has often been isolated from symptomatic host plants together with other *Fusarium* species and/or other fungal genera. In those cases, symptoms caused by *F. brachygibbosum* have been demonstrated experimentally based on pathogenicity tests. As an example, using 2-year-old detached almond branches inoculated with *F. brachygibbosum* and stored at 15°C for 14 days, cankers were developed which were comparable to those caused by two other species (*F. acuminatum* and *F. avenaceum*) pathogenic to almond. *F. brachygibbosum* was also isolated from asymptomatic almond rootstocks (Seidle, 2016). In artificially inoculated watermelon, *F. brachygibbosum* produced light-brown lesions variable in size at collar and root level, causing wilting of leaves or whole plants (Rentería-Martínez et al., 2015). The

[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).

pathogen also generated dark brown to black, circular to elliptical leaf spots in oleander (Mirhosseini et al., 2014). *F. brachygibbosum* was isolated in South Africa, along with several other *Fusarium* species, from kernels of field-grown wheat exhibiting symptoms of Fusarium head blight disease (Van Coller et al., 2013).

In some instances, pathogenicity tests highlighted a weak ability of the pathogen to induce disease symptoms on artificially inoculated plants (Tan et al., 2011; Al-Sadi et al., 2012; Al-Nadabi et al., 2020; Özer et al., 2020). Therefore, uncertainty exists on (a) the specific role of *F. brachygibbosum* in the aetiology of observed diseases in some of the reported hosts, since the pathogen has been often found in conjunction with other fungal species and (b) the real aggressiveness of *F. brachygibbosum* since pathogenicity tests have highlighted weak symptoms on some hosts.

Isolates of *F. brachygibbosum* were reported to be able to produce different mycotoxins: For instance, isolates from date palms affected by quick sudden syndrome symptoms produced low levels of beauvericin A, T-2 and HT-2 toxins (Rabaaoui et al., 2021), whereas isolates from *Trifolium subterraneum* produced low levels of fusarenone-X and some type A trichothecene derivatives (Tan et al., 2011).

Noteworthy, *F. brachygibbosum* has also been reported as a clinically relevant human pathogen (O'Donnell et al., 2009; Al-Hatmi et al., 2016; Pérez-Nadales et al., 2021). A strain isolated from human hair has been recently shown to produce active keratinase (Alwakeel et al., 2021).

3.1.3. Host range

Infection by *F. brachygibbosum* has been so far reported from different cultivated hosts including *Allium cepa* (Tirado-Ramirez et al., 2021), *Beta vulgaris* (Cao et al., 2018), *Cannabis sativa* (Punja et al., 2018, 2019), *Citrullus lanatus* (Rentería-Martínez et al., 2015), *Citrus limettioides* (Al-Sadi et al., 2014), *Citrus aurantium* (Ezrari et al., 2021), *Euphorbia larica* (Al-Mahmooli et al., 2013), *Fragaria x ananassa* (Mariscal-Amaro et al., 2017), *Glycine max* (Wang et al., 2021), *Gossypium hirsutum* (Le et al., 2020), *Mentha piperita* (Habibi et al., 2018), *Nerium oleander* (Mirhosseini et al., 2014), *Nicotiana tabacum* (Qiu et al., 2021), *Olea europaea* (Trabelsi et al., 2017), *Phoenix dactylifera* (Al-Sadi et al., 2012; Saleh et al., 2017; Al-Nadabi et al., 2020; Namsi et al., 2020; Nishad and Ahmed, 2020; Rabaaoui et al., 2021), *Prunus dulcis* (Seidle, 2016; Stack et al., 2017), *Sansevieria trifasciata* (Kee et al., 2020), *Solanum lycopersicum* (Khamas et al., 2021), *Solanum tuberosum* (Zimudzi et al., 2017; Azil et al., 2021), *Sorghum vulgare* (Padwick, 1945), *Trifolium subterraneum* (Tan et al. 2011), *Triticum aestivum* (Ali et al., 2020; Özer et al., 2020; Mohammed-Ameen et al., 2021), *Triticum* sp. (Van Coller et al., 2013), *Vitis vinifera* (Akgül and Ahioğlu, 2019), *Zea mays* (Shan et al., 2017; Fallahi et al., 2019).

F. brachygibbosum has also been reported as pathogen on sunflower broomrape (*Orobanche cumana*; Xia et al., 2018) and on the Mediterranean perennial alfa grass (*Stipa tenacissima*; Gargouri et al., 2018).

Considering the fact that *F. brachygibbosum* is a cosmopolitan common soil-borne filamentous fungus pathogenic on certain plant hosts, and that it is often reported in mixed infections with other fungal species, this pest categorisation focuses on those hosts for which there is robust evidence in the literature that the pathogen was isolated and identified by both morphology and molecular analyses, and Koch's postulates were fulfilled. Based on the above, the following cultivated species are considered as proven hosts of *F. brachygibbosum*:

- *Allium cepa* (Tirado-Ramirez et al., 2021);
- *Beta vulgaris* (Cao et al., 2018);
- *Cannabis sativa* (Punja et al., 2018, 2019);
- *Citrullus lanatus* (Rentería-Martínez et al., 2015);
- *Citrus* spp. (Al-Sadi et al., 2014);
- *Glycine max* (Wang et al., 2021);
- *Nerium oleander* (Mirhosseini et al., 2014);
- *Nicotiana tabacum* (Qiu et al., 2021)
- *Phoenix dactylifera* (Al-Sadi et al., 2012; Saleh et al., 2017; Al-Nadabi et al., 2020; Namsi et al., 2020; Nishad and Ahmed, 2020; Rabaaoui et al., 2021);
- *Prunus dulcis* (Seidle, 2016; Stack et al., 2017);
- *Solanum tuberosum* (Zimudzi et al., 2017; Azil et al., 2021);
- *Sorghum vulgare* (Padwick, 1945);
- *Trifolium subterraneum* (Tan et al. 2011);

- *Triticum* spp. (Ali et al., 2020; Özer et al., 2020; Mohammed-Ameen et al., 2021; Van Coller et al., 2013);
- *Vitis vinifera* (Akgül and Ahioğlu, 2019);
- *Zea mays* (Shan et al., 2017; Fallahi et al., 2019).

The complete list of the host plants reported so far for *F. brachygibbosum* is included in **Appendix B** (last updated: 28 June 2012). However, uncertainty exists about the actual host range, since the pathogen was found on taxonomically different host species and the number of new reports has flourished during the last 5 years.

3.1.4. Intraspecific diversity

Intraspecific diversity has not been described and in most cases only single isolates were tested in pathogenicity experiments (e.g. Al-Sadi et al., 2012; Akgül and Ahioğlu, 2019; Ali et al., 2020; Al-Nadabi et al., 2020; Özer et al., 2020; Azil et al., 2021; Wang et al., 2021). However, inoculation of 14 *F. brachygibbosum* isolates on sugar beet (*Beta vulgaris* subsp. *vulgaris*) highlighted disease severity indexes ranging from 17.5 to 71.7 in a scale up to 100 (Cao et al., 2018), thereby suggesting some degree of intraspecific diversity affecting aggressiveness on the same host.

3.1.5. Detection and identification of the pest

Are detection and identification methods available for the pest?
Yes, detection and identification methods are available.

Different host plants infected by *F. brachygibbosum* may show a wide range of symptoms, including crown and root rot, or tuber rot, stalk rot, ear rot, canker, wilting, leaf spot, decline and dieback (See Section 3.1.2 'Biology of the pest'. These symptoms are not specific to the pathogen, which is often found in infected tissues along with a complex of other fungal species. In addition, host plants and plant products that are latently infected by *F. brachygibbosum* are unlikely to be detected during visual inspection.

F. brachygibbosum was first described based on its morphology by Padwick (1945), and later identified based on biochemical characteristics, including the sequencing of large subunit (26S) ribosomal DNA (O'Donnell et al., 2009; O'Donnell et al., 2010). Initially identified as member of the FIESC (*Fusarium incarnatum–Fusarium equiseti* species complex) or FCSC (*Fusarium chlamydosporum* species complex) based on morphology, it was later resolved as a phylogenetically distinct species nested outside these two complexes, based on comparisons of partial *EF-1* and *RPB2* gene sequences (O'Donnell et al., 2009). The increased frequency of *F. brachygibbosum* detection worldwide on different hosts during the last few years than earlier is likely due to the availability of new molecular tools able to distinguish this pathogen from other coexisting *Fusarium* species (Chitambar, 2016).

In culture, the colonies of *F. brachygibbosum* consist of aerial mycelium abundant on PDA, white and pink, medium blood coloured. Typical microconidia are 1–3 septate, 5.4–15.5 μm long × 2.0–3.2 μm wide, ovoid to fusiform, those septate are slightly curved. Macroconidia are often hyperbolically curved, 17.0–45.9 μm long × 3.0–4.6 μm wide, with three to five distinct septa, wide central cells, slightly sharp apexes and tapering or rarely slightly foot-celled base (Figure 1). The fungus is able to form terminal and intercalary spherical chlamydospores, one-celled and globose, occasionally two-celled, smooth, granular, 12.4 (10.7–15.3 μm), that can be abundant on carnation leaf agar (CLA) after 4 weeks (Padwick, 1945; Stack et al., 2017). Sclerotia (up to 2 mm diam., white to amber) are formed on PDA or steamed rice at 20°C, but not at 30°C (Padwick, 1945).

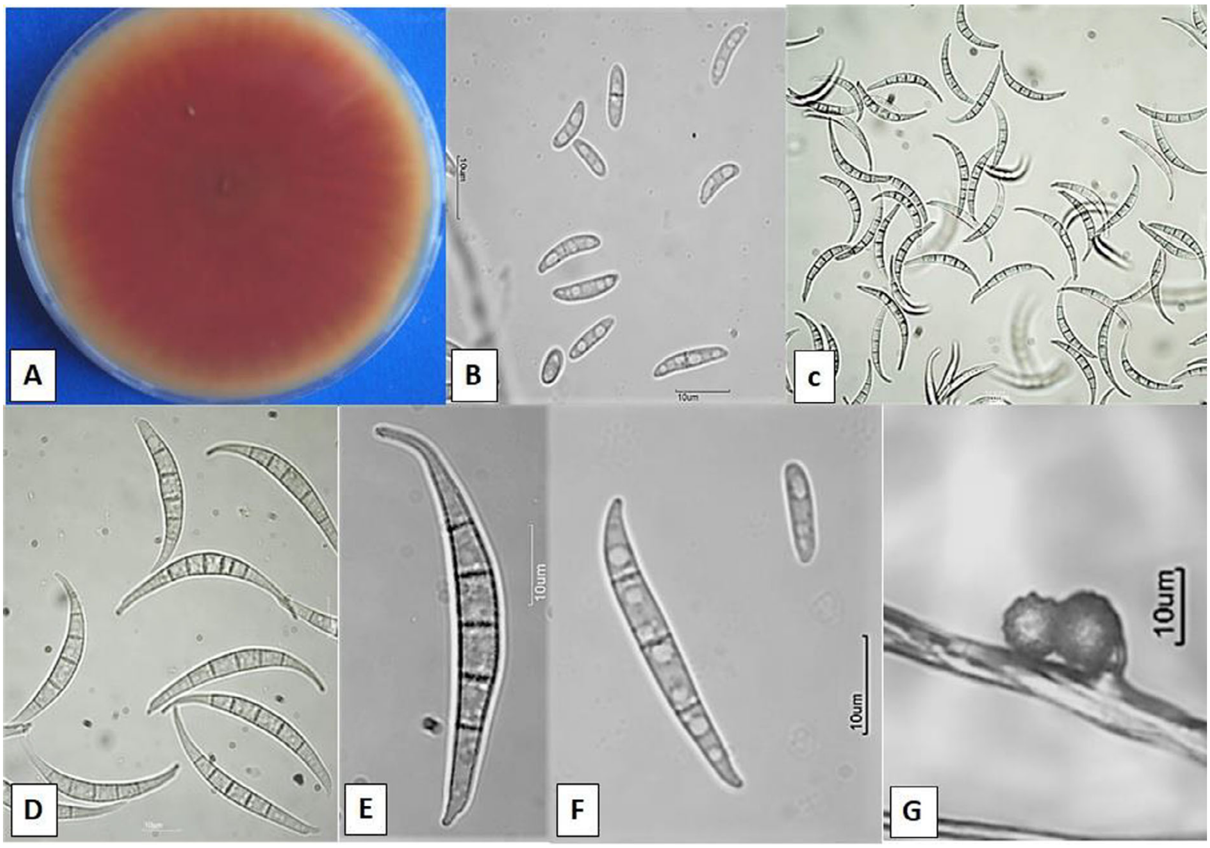

Figure 1: Morphological traits of two distinct isolates of *Fusarium brachygibbosum* in culture. **A** = 7-d-old colony on PDA; **B** = microconidia; **C** = macroconidia (20x); **D** = macroconidia (40x); **E**–**F** = macroconidia (100×); **G** = chlamydospores (courtesy: Prof. Virgilio Balmas, University of Sassari)

Morphological characteristics (particularly the shape of macroconidia) may be observed from monosporic cultures in CLA or PDA, but such traits are shared with other *Fusarium* species, particularly in the FIESC (O'Donnell et al., 2009) and are therefore not exclusive to *F. brachygibbosum*.

Molecular methods such as multigene (Ef-1a, RPB1 and RPB2) sequence analysis are available in the literature (Geiser et al., 2004; O'Donnell et al., 2010) and can be used in combination with morphology-based methods (Padwick, 1945) for the identification of *F. brachygibbosum*.

In conclusion, the broad host range, the lack of specific symptoms and of species-specific morphological traits, coupled with a frequently reported weak aggressiveness and co-isolation with other pathogenic fungi, may have possibly led to underestimation of the presence of *F. brachygibbosum* as a common soil inhabitant in natural and agricultural settings (Balmas et al., 2010; González-Delgado et al., 2017; Mojela, 2017; Panelli et al., 2017).

No EPPO Standard is available for the detection and identification of *F. brachygibbosum*.

3.2. Pest distribution

3.2.1. Pest distribution outside the EU

F. brachygibbosum is reported from Asia, Africa, America and Oceania (see Figure 2).

In Asia, the pathogen is reported from China (Shan et al., 2017; Cao et al., 2018; Xia et al., 2018; Qiu et al., 2021; Wang et al., 2021), Malaysia (Kee et al., 2020), India (Padwick, 1945), Iran (Davari et al., 2014; Mirhosseini et al., 2014; Habibi et al., 2018; Fallahi and Saremi, 2020), Iraq (Ali et al., 2020; Khamas et al., 2021; Mohammed-Ameen et al., 2021), Azerbaijan (Özer et al., 2020), Oman (Al-Sadi et al., 2012; Al-Mahmooli et al., 2013; Al-Nadabi et al., 2020), Qatar (Nishad and Ahmed, 2020), Saudi Arabia (Saleh et al., 2017), Turkey (Akgül and Ahioğlu, 2019).

In Africa, the pathogen is reported from Algeria (Azil et al., 2021), Morocco (Ezrari et al., 2021), Tunisia (Trabelsi et al., 2017; Gargouri et al., 2018; Namsi et al., 2020; Rabaaoui et al., 2021) and South Africa (Van Coller et al., 2013; Mojela, 2017; Zimudzi et al., 2017; Sandoval-Denis et al., 2018).

In America, *F. brachygibbosum* is reported from Mexico (Rentería-Martínez et al., 2015; González-Delgado et al., 2017; Mariscal-Amaro et al., 2017; Tirado-Ramirez et al., 2021) and USA (Seidle, 2016; Stack et al., 2017; Punja et al. 2018, 2019).

In Oceania, this fungus is reported from Australia (Tan et al., 2011; Le et al., 2020).

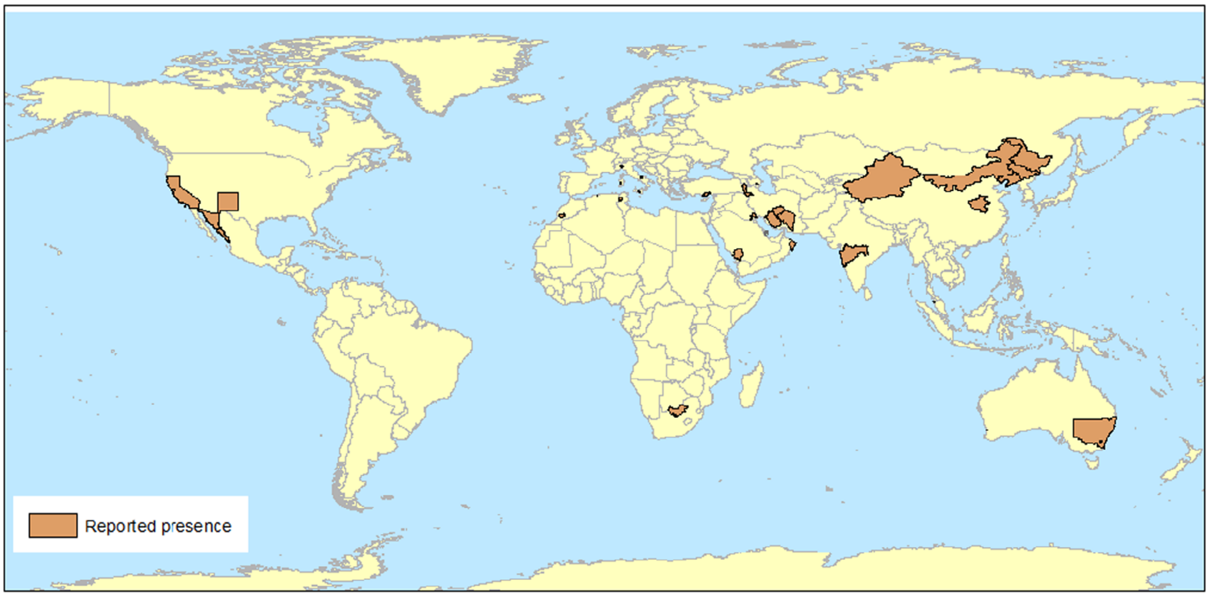

Figure 2: Global distribution of *Fusarium brachygibbosum* (Source: literature)

Details of the current distribution of the pathogen outside the EU are presented in **Appendix A** (last updated: 29 June 2021). No map on the global distribution of *F. brachygibbosum* is available in the EPPO Global Database.

There is uncertainty about the distribution of the pathogen outside the EU, as in the past, when molecular tools (i.e. multilocus phylogenetic analysis) were not available, the pathogen might have been misidentified based on morphology. Such uncertainty is further confirmed by the fact that most of the reports have occurred during the last 5 years.

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, *F. brachygibbosum* is reported to be present in the EU (Italy) in soil/marine sediment. The pathogen has also been detected in quinoa and durum wheat seeds produced in Italy. The pest is not widely distributed within the EU with high uncertainty.

F. brachygibbosum has been reported from Italy, namely from the regions of Sardinia (Balmas et al. 2010, Oufensou et al., 2021), Lombardy (Panelli et al., 2017), Sicily (Bovio et al., 2017) and Molise (Oufensou et al., 2021).

In the reports from Sardinia (Balmas et al., 2010), Lombardy (Panelli et al., 2017) and Sicily (Bovio et al., 2017), *F. brachygibbosum* has not been associated with plant disease, as it was recovered from undisturbed (Balmas et al., 2010) and cultivated (Panelli et al., 2017) soils, or from a marine sediment contaminated by oil spill (Bovio et al., 2017). In the report by Balmas et al. (2010), there are no uncertainties as per the identification of the fungus, that was based on multilocus sequencing, whereas in the other two reports, identification was based either on a metagenomic analysis (Panelli et al., 2017) or on morphology and ITS1-5,8S-ITS2 region sequencing (Bovio et al., 2017), thereby posing some uncertainty on the accurate identification of the pathogen and thus on its presence in the two reported areas.

F. brachygibbosum was also isolated in 2019 and 2020 from quinoa (*Chenopodium quinoa*) seeds produced in Sardinia (Santa Lucia, Oristano Province) and from kernels of durum wheat (*Triticum durum)* grown in the Region of Molise, respectively (Oufensou et al., 2021). This should be considered as the first report of the presence of *F. brachygibbosum* on cultivated hosts in Europe. The status of the pest is currently under investigation by the competent authority.

Nevertheless, uncertainty exists about the current distribution of *F. brachygibbosum* in the EU, as in the past, when molecular tools (i.e. multilocus phylogenetic analysis) were not available, the fungus might have been identified as an FIESC or FCSC member based on morphology and pathogenicity tests, which cannot reliably identify this species based on the current taxonomic criteria.

3.3. Regulatory status

3.3.1. Commission Implementing Regulation 2019/2072

F. brachygibbosum is not listed in Annex II of Commission Implementing Regulation (EU) 2019/2072, the implementing act of Regulation (EU) 2016/2031.

3.3.2. Hosts of *F. brachygibbosum* that are prohibited from entering the Union from third countries

Table 2 presents a list of plant products and other objects that are *Fusarium brachygibbosum* hosts and whose introduction into the European Union from certain third countries is prohibited.

Table 2: List of plants, plant products and other objects that are *Fusarium brachygibbosum* hosts whose introduction into the Union from certain third countries is prohibited (Source Commission Implementing Regulation (EU) 2019/2072, Annex VI). Some of the hosts such as *Nerium* and *Prunus* are included in the Commission Implementing Regulation (EU) 2018/2019 on high-risk plants

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**
8.	Plants for planting of [. . ..], *Prunus* L., [. . ...], other than dormant plants free from leaves, flowers and fruits	ex 0602 10 90 ex 0602 20 20 ex 0602 20 80 ex 0602 40 00 ex 0602 90 41 ex 0602 90 45 ex 0602 90 46 ex 0602 90 47 ex 0602 90 48 ex 0602 90 50 ex 0602 90 70 ex 0602 90 91 ex 0602 90 99	Third countries other than Albania, Andorra, Armenia, Azerbaijan, Belarus, Bosnia and Herzegovina, Canary Islands, Faeroe Islands, Georgia, Iceland, Liechtenstein, Moldova, Monaco, Montenegro, North Macedonia, Norway, Russia (only the following parts: Central Federal District (Tsentralny federalny okrug), Northwestern Federal District (Severo-Zapadny federalny okrug), Southern Federal District (Yuzhny federalny okrug), North Caucasian Federal District (Severo-Kavkazsky federalny okrug) and Volga Federal District (Privolzhsky federalny okrug)), San Marino, Serbia, Switzerland, Turkey, Ukraine and the United Kingdom (1)
9.	Plants for planting of [. . .. .]*Prunus* L. and [. . .. .] and their hybrids, and *Fragaria* L.], other than seeds	ex 0602 10 90 ex 0602 20 20 ex 0602 90 30 ex 0602 90 41 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 Albania, Algeria, Andorra, Armenia, Australia, Azerbaijan, Belarus, Bosnia and Herzegovina, Canada, Canary Islands, Egypt, Faeroe Islands, Georgia, Iceland, Israel, Jordan, Lebanon, Libya, Liechtenstein, Moldova, Monaco, Montenegro, Morocco, New Zealand, North Macedonia, Norway, Russia (only the following parts: Central Federal District (Tsentralny federalny okrug), Northwestern Federal District (Severo- Zapadny federalny okrug), Southern Federal District (Yuzhny federalny okrug), North Caucasian Federal District (Severo- Kavkazsky federalny okrug) and Volga Federal District (Privolzhsky federalny okrug)), San Marino, Serbia, Switzerland, Syria, Tunisia, Turkey, Ukraine, the United Kingdom (1) and United States other than Hawaii

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**
10.	Plants of *Vitis* L., other than fruits	0602 10 10 0602 20 10 ex 0604 20 90 ex 1404 90 00	Third countries other than Switzerland
11.	Plants of *Citrus* L., [.........], and their hybrids, other than fruits and seeds	ex 0602 10 90 ex 0602 20 20 0602 20 30 ex 0602 20 80 ex 0602 90 45 ex 0602 90 46 ex 0602 90 47 ex 0602 90 50 ex 0602 90 70 ex 0602 90 91 ex 0602 90 99 ex 0604 20 90 ex 1404 90 00	All third countries
13.	Plants of *Phoenix* spp. other than fruit and seeds	ex 0602 20 20 ex 0602 20 80 ex 0602 90 41 ex 0602 90 45 ex 0602 90 46 ex 0602 90 47 ex 0602 90 50 ex 0602 90 70 ex 0602 90 99 ex 0604 20 90 ex 1404 90 00	Algeria, Morocco
15.	Tubers of *Solanum tuberosum* L., seed potatoes	0701 10 00	Third countries other than Switzerland
16.	Plants for planting of stolon- or tuber-forming species of *Solanum* L. or their hybrids, other than those tubers of *Solanum tuberosum* L. as specified in entry 15	ex 0601 10 90 ex 0601 20 90 ex 0602 90 50 ex 0602 90 70 ex 0602 90 91 ex 0602 90 99	Third countries other than Switzerland
19.	Soil as such consisting in part of solid organic substances	ex 2530 90 00 ex 3824 99 93	Third countries other than Switzerland
20.	Growing medium as such, other than soil, consisting in whole or in part of solid organic substances, other than that composed entirely of peat or fibre of *Cocos nucifera* L., previously not used for growing of plants or for any agricultural purposes	ex 2530 10 00 ex 2530 90 00 ex 2703 00 00 ex 3101 00 00 ex 3824 99 93	Third countries other than Switzerland

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, the pest already entered the EU territory. It could further enter the EU territory via the host plant for planting, seed of host plants and the soil or other substrates.

The PLH Panel identified the following main pathways for the entry of the pathogen into the EU territory:

1) host plants for planting,
2) seed of host plants,
3) soil and other substrates,

originating in infested third countries (Table 4).

F. brachygibbosum has been found as a common soil inhabitant, and in general, *Fusarium* species are strong competitors in soil (see Section 3.1.2 Biology of the pest). Therefore, besides plants for planting and seeds of host plants, soil and other substrates associated or not with host plants for planting represent a potential pathway of further entry of the pathogen into the EU territory. The pathogen could potentially enter the EU through the fruits and seeds of host plants for consumption. However, this pathway is of minor importance because of the unlikely event of the pathogen's transfer from the pathway to the hosts grown in the EU territory.

The pathogen is unlikely to enter new areas of the EU by natural means (wind, rain, insect vectors, etc.) because of the long distance between the infested third countries and the EU Member States. Although there are no quantitative data available, different types of propagules (mycelium, micro- and macroconidia, chlamydospores, sclerotia) of the pathogen may be also present as contaminants on other substrates (e.g. non-host plants for planting or seed, plant debris and contaminated machinery and equipment) imported into the EU from infested third countries.

Given its biology, *F. brachygibbosum* could potentially be transferred from the pathways of entry to the host plants grown in the EU via the contaminated soil, irrigation water as well as the wind-disseminated and splash-dispersed spores. The frequency of this transfer will depend on the volume and frequency of imported commodities.

Table 3: Potential entry pathways for *Fusarium brachygibbosum* into the EU 27

Pathways	Life stage	Relevant mitigations [e.g. prohibitions (Annex VI) or special requirements (Annex VII) within Implementing Regulation 2019/2072]
Plants for planting of *Prunus* L. other than dormant plants free from leaves, flowers and fruits	Mycelium, micro- and macroconidia	Annex VI (8.) bans the introduction of plants for planting of *Prunus* with leaves, flowers and fruits from certain third countries. Two of the third countries from where the introduction of *Prunus* plants for planting with leaves, flowers and fruits is permitted, i.e. Turkey, Azerbaijan, has been reported to be infested by *F. brachygibbosum*
Plants for planting of *Prunus* L. and their hybrids, and *Fragaria* L., other than seeds	Mycelium, micro- and macroconidia	Annex VI (9.) bans the introduction of plants for planting of *Prunus* L. and their hybrids, and Fragaria L., other than seeds from certain third countries. Five of the third countries from where the introduction of *Prunus* plants for planting with leaves, flowers and fruits and *Fragaria* plants for planting is permitted, i.e. Azerbaijan, Morocco, Tunisia, Turkey and United States (other than Hawaii), have been reported to be infested by *F. brachygibbosum*
Plants for planting of *Citrus* L.[......], and their hybrids	Mycelium, micro- and macroconidia	Annex VI (11.) bans the introduction of plants of *Citrus* L., and their hybrids, other than fruits and seeds from all third countries

Pathways	Life stage	Relevant mitigations [e.g. prohibitions (Annex VI) or special requirements (Annex VII) within Implementing Regulation 2019/2072]
Plants of *Vitis* L., other than fruits	Mycelium, micro- and macroconidia	Annex VI (10.) bans the introduction of plants of *Vitis* L., other than fruits from third countries other than Switzerland
Plants of *Phoenix* spp. other than fruit and seeds	Mycelium, micro- and macroconidia	Annex VI (13.) bans the introduction of plants of *Phoenix* spp., other than fruits and seeds from Algeria and Morocco.
Tubers of *Solanum tuberosum* L., seed potatoes	Mycelium, micro- and macroconidia	Annex VI (15.) bans the introduction of tubers *of Solanum tuberosum* L. seed potatoes from third countries other than Switzerland
Plants for planting of stolon- or tuber-forming species of *Solanum* L. or their hybrids, other than those tubers of *Solanum tuberosum* L. as specified in entry 15	Mycelium, micro- and macroconidia	Annex VI (16) bans the introduction of plants for planting of stolon- or tuber-forming species of *Solanum* L. or their hybrids, other than those tubers of *Solanum tuberosum* L. as specified in entry 15 from third countries other than Switzerland
Seeds of wheat and meslin	Mycelium, micro- and macroconidia	Annex XI, A requires phytosanitary certificate for the introduction into the Union territory from certain third countries among which India, Iran, Iraq, Mexico, South Africa and United States are listed, where the pest is known to occur
Seeds of *Trifolium* spp. and sorghum	Mycelium, micro- and macroconidia	Annex XI, A requires phytosanitary certificate for the introduction into the Union territory from certain countries among which Australia is listed where the pest is known to occur.
Seeds of *Citrus* L. [………], and their hybrids, [……], *Prunus* L., *Zea mays* L., *Allium cepa* L.,	Mycelium, micro- and macroconidia	Annex XI, A requires phytosanitary certificate for the introduction into the Union territory from third countries other than Switzerland.
Seeds of *Glycine max* L.	Mycelium, micro- and macroconidia	Annex XI, A requires phytosanitary certificate for the introduction into the Union territory from third countries
Soil and other substrates associated or not with host plants for planting	Chlamydospores, sclerotia	Annex VI (19., 20.) bans the introduction into the Union from third countries other than Switzerland of soil as such and growing medium as such other than soil consisting in whole or in part of solid organic substances, other than that composed entirely of peat or fibre of *Cocos nucifera* L., previously not used for growing of plants or for any agricultural purposes.
Growing medium attached to or associated with plants intended to sustain the vitality of the plants	Chlamydospores, sclerotia	Annex XI A (1.) requires phytosanitary certificate for growing medium, attached to or associated with plants, intended to sustain the vitality of the plants originating in third countries other than Switzerland.
Sugar beet (*Beta vulgaris* L.), fresh, intended for industrial use	Mycelium, micro- and macroconidia	Annex XII requires phytosanitary certificate for the introduction into a protected zone [i.e. Ireland, France (Brittany), Portugal (Azores), Finland and UK (Northern Ireland)] from all third countries other than Switzerland.
Seeds for sowing of *Beta vulgaris* L., *Nicotiana tabacum* L., *Cannabis sativa* L. and *Nerium oleander* L.	Mycelium, micro- and macroconidia	
Plants for planting of *Nerium oleander* L.	Mycelium, micro- and macroconidia	

Pathways	Life stage	Relevant mitigations [e.g. prohibitions (Annex VI) or special requirements (Annex VII) within Implementing Regulation 2019/2072]
Machinery and vehicles which have been operated for agricultural or forestry purposes	Chlamydospores, sclerotia	Annex VII (2.) requires official statement that the machinery or vehicles are cleaned and free from soil and plant debris Annex XI, A (1.) requires phytosanitary certificate for the introduction into the Union territory from third countries other than Switzerland.

Table 4: EU 27 annual imports of fresh produce of main hosts from countries where *Fusarium brachygibbosum* is present, 2016–2020 (in 100 kg) Source: EUROSTAT accessed on 19/7/2021

Commodity	HS code	2016	2017	2018	2019	2020
Onions, fresh or chilled	070310	506,399.74	1,160,663.77	442,689.00	317,410.12	606,299.29
Sugar beet,	1212 91	0.03	1.89	2.72	2.45	1,121.2
Live outdoor plants, incl. their roots	060290	25,960.48	26,553.82	10,710.29	12,420.31	12,014.05
Soya beans	1201	48,766,338.9	67,805,868.4	74,380,408.6	46,753,067.4	53,409,156.27
Fresh or dried almonds in shell	0802 11	28,964.81	29,093.55	24,202.82	49,317.85	22,485.99
Fresh or dried almonds, shelled	0802 12	2,744,414.51	2,494,192.36	2,546,285.56	2,503,112.41	2,459,779.26
Potatoes, fresh or chilled	0701 90	135,178.18	401,553.21	60,444.24	181,206.97	201,453.61
Grain sorghum	1007	23,998.69	4,186,543.21	5,217,013.98	13,553.8	27,848.98
Bulbs, tubers, tuberous roots, corms, crowns and rhizomes	0601 20	17,708.88	17,564.81	19,052.5	12,160.65	12,367.57
Wheat and meslin	1001	10,818,965.6	8,440,749.58	7,562,775.49	7,834,308.49	9,957,570.98
Vine slips, grafted or rooted	0602 20 10	3	120	0.01	8.09	0
	Sum	63,067,932.77	84,562,904.57	90,263,585.23	57,676,568.55	66,710,097.20

Notifications of interceptions of harmful organisms began to be compiled in Europhyt in May 1994 and in TRACES in May 2020. No interceptions specific for *F. brachygibbosum* were found. However, 10 interceptions of *Fusarium* and *Fusarium* sp. are reported in Europhyt with the last interception in 2016 (accessed on 29 June 2021).

3.4.2. Establishment

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

Yes. The pest could further establish in the risk assessment area.

3.4.2.1. EU distribution of main host plants

In Table 5, the EU distribution of the proven host plants of *F. brachygibbosum* is outlined.

Table 5: Harvested area of *Fusarium brachygibbosum* proven hosts in EU 27, 2016–2020 (1,000 ha). Source EUROSTAT (accessed 19/7/2021) https://ec.europa.eu/eurostat/databrowser/view/apro_cpsh1/default/table?lang=en

Crop	2016	2017	2018	2019	2020
Wheat and spelt	25,210.30	24,138.62	23,751.66	24,210.19	22,802.51
Sorghum	123.77	135.66	147.85	190.32	226.84
Soya	831.18	962.39	955.40	907.91	939.80
Watermelon	75.31	76.47	73.54	74.57	73.75
Onions	169.93	170.68	171.78	176.63	176.29
Shallots	2.49	2.40	2.39	2.41	2.43
Beetroot	23.38	23.51	24.25	25.12	24.88
Citrus fruits	519.01	502.84	508.99	512.53	487.08
Grapes	3,136.04	3,134.93	3,137.17	3,160.68	3,162.48

':' data not available.

3.4.2.2. Climatic conditions affecting establishment

F. brachygibbosum has been reported from all continents except the Arctic and Antarctica. Limited data are available on the exact location of the areas of the current global distribution of *F. brachygibbosum.* Nevertheless, based on the few data available, the climatic zones in parts of United States, Mexico, Algeria, Morocco, Tunisia, South Africa, Zimbabwe, Azerbaijan, China, India, Iran, Iraq, Malaysia, Oman, Qatar, Saudi Arabia, Turkey, Australia, where the pathogen is present, are comparable to climatic zones within the EU (Figure 3). The climate zones in the areas in Italy from where the pathogen has been reported also occur in some other parts of the EU.

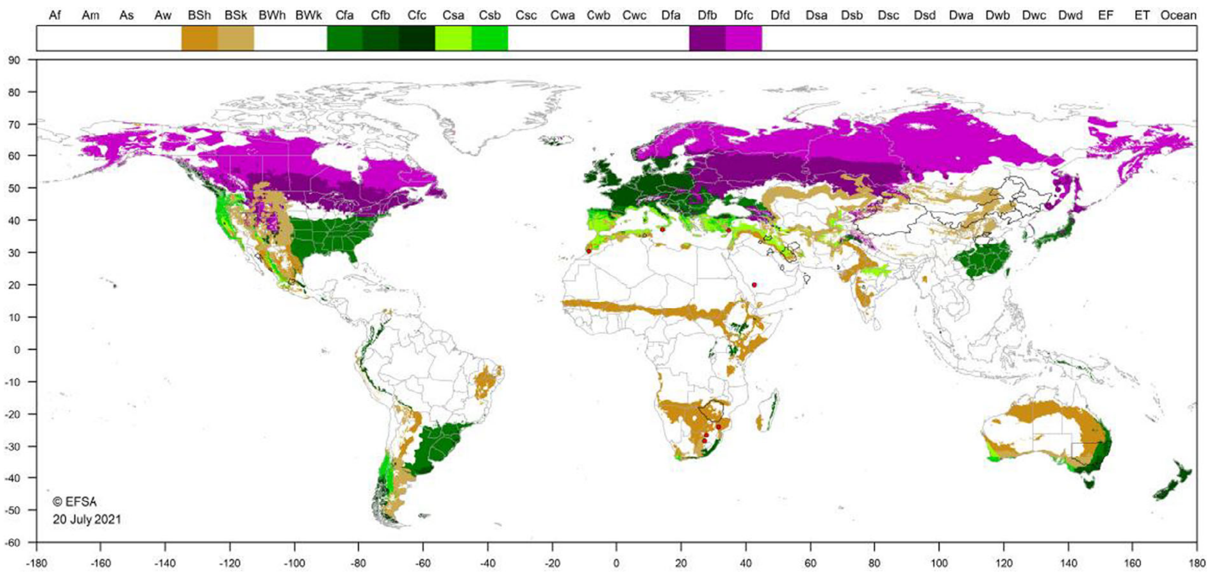

Figure 3: World distribution of Köppen–Geiger climate types that occur in the EU and in non-EU areas where *Fusarium brachygibbosum* has been reported

The global Köppen–Geiger climate zones (Kottek et al., 2006) describe terrestrial climate in terms of average minimum winter temperatures and summer maxima, amount of precipitation and seasonality (rainfall pattern). *F. brachygibbosum* occurs in several climate zones, namely: Csa, BSk, Cfa, Cfb, Csb, Dfb, Dfc and Cfc. These climate zones also occur in the EU territory, where hosts of the pathogen are grown.

Uncertainty exists about the distribution of *F. brachygibbosum* in the EU, given that in the past this fungus might have been previously identified as an FIESC or FCSC member based on morphology alone.

3.4.3. Spread

Describe how the pest would be able to spread within the EU territory following establishment?
All pests must be able to spread, even if only very small distances, or very slowly. The question should not ask "can" but "how" i.e. by what means/mechanism
Fusarium brachygibbosum would be able to spread within the EU by both natural and human-assisted means.

Sources: EPPO GD; CABI and/or Literature

Following its introduction into the EU territory, *F. brachygibbosum*, similarly to other *Fusarium* species, could potentially spread via natural and human-assisted means.

Spread by natural means. *F. brachygibbosum* overwinters as mycelium or spores in infected plant residues and in seed, or as chlamydospores and sclerotia in soil (Padwick, 1945; Chitambar, 2016; Stack et al., 2017). Asexual spores (microconidia and macroconidia) are dispersed locally by wind, water or rain-splash.

Spread by human assistance. The pathogen could potentially spread over long distances via the movement of infected host plants for planting, roots, stems, leaves, seeds (Van Coller et al., 2016), soil and substrates and contaminated equipment (Chitambar, 2016).

3.5. Impacts

Would the pests' introduction have an economic or environmental impact on the EU territory?
Yes, despite the low aggressiveness observed in most reported hosts, and the fact that *F. brachygibbosum* has often been found associated to a complex of other fungal species in infected plants, it has been shown that the pathogen may have a direct impact on some crops (e.g., almond, onion, soybean, tobacco) that are relevant for the EU.

F. brachygibbosum is a soil-borne filamentous fungal pathogen with opportunistic behaviour, characterised by a broad distribution worldwide. Occasionally, it can be responsible for economic losses due to yield reduction in different cultivated hosts (Punja et al., 2018). However, specific losses due to *F. brachygibbosum* are rarely reported (Chitambar, 2016). In most disease reports, more than one *Fusarium* species and/or fungal species of other genera may be present in the affected crops (e.g. Al-Sadi et al., 2012; Mariscal-Amaro et al., 2017; Saleh et al., 2017; Trabelsi et al., 2017; Zimudzi et al., 2017; Cao et al., 2018; Akgül and Ahioğlu, 2019; Al-Nadabi et al., 2020; Le et al., 2020; Namsi et al., 2020; Özer et al., 2020; Azil et al., 2021; Ezrari et al., 2021; Khamas et al., 2021; Mohammed-Ameen et al., 2021).

Quantitative estimates of losses in crop yield have been reported only in a few cases for *F. brachygibbosum*. The so far most noticeable economic impact is reported from California in young almond nursery rooting (Marek et al., 2013; Seidle et, 2016). The pathogen has been hypothesised to establish primarily in nurseries with bare-root propagative almond plants predisposed to abiotic stresses – including temperature variations in cold storage, and in almond production fields (Chitambar, 2016).

In China, *F. brachygibbosum* has been reported to cause damage on approximately 65% of soybean plants grown over a surface of > 10 ha (Wang et al., 2021). Qiu et al. (2021) reported a disease incidence ranging from 15% to 40% on tobacco in 11 surveyed fields in China, accounting for over 36 ha.

Uncertainty exists on the efficacy of the agricultural practices and chemical disease control measures currently applied in the EU in reducing the impact of pest introduction.

Uncertainty exists on the potential impact of the pathogen on some of the reported host crops grown in EU (such as maize, citrus, grapevine, onion, potato, sugar beet, sorghum, watermelon, wheat) due to the fact that no quantitative data are available.

3.6. Available measures and/or potential specific import requirements and limits of mitigation measures

Are there measures available to prevent the entry into the EU such that the risk becomes mitigated?

Yes. Although not specifically targeted against *F. brachygibbosum*, existing phytosanitary measures (see sections 3.3.2 and 3.4.1) mitigate the likelihood of the pathogen's entry on certain host plants, plant products and other objects into the EU territory. Potential additional measures are also available to further mitigate the risk of entry and spread of the pathogen in the EU (see section 3.6.1).

3.6.1. Identification of potential additional measures

Phytosanitary measures (prohibitions) are currently applied to some hosts of *F. brachygibbosum*, although measures in Annex VII of Commission Implementing Regulation 2019/2072 do not specifically refer to this pest (see Section 3.3.2).

Potential additional control measures are listed in Table 6.

Table 6: Selected control measures (a full list is available in EFSA PLH Panel, 2018) for pest entry and spread in relation to currently unregulated hosts and pathways

Special requirements summary (with hyperlink to information sheet if available)	Control measure summary in relation to *Fusarium brachygibbosum*
Pest freedom	*Used to mitigate likelihood of infestation by specified pest at origin, hence to mitigate entry* Plant or plant products come from a country officially free from the pest, or from a pest-free area or from a pest-free place of production.
Managed growing conditions	*Used to mitigate likelihood of infestation at origin* *Fusarium* species may inhabit soils and plants. They can exist saprophytically, but can also act as opportunistic pathogens. On hosts predisposed by stress, or in combination with other pathogens, symptoms may become severe. Hot and humid environmental conditions support the spread of these pathogens. Hence, the use of pathogen-free propagative material, proper field drainage, avoidance of unclean water for canopy irrigation, plant distancing, destroying infected parts of plants into small pieces for faster decomposition using limes, crop rotation and removal of any infected plant parts in the field represent effective methods to manage *F. brachygibbosum*.
Growing plants in isolation	*Used to mitigate likelihood of infestation by specified pest in vicinity of growing site* The use of transplants raised from pathogen-free propagative material, as well as growing transplants in areas that are not planted with other crops that are known hosts of *F. brachygibbosum* may represent an effective control measure.
Certification of reproductive material (voluntary/official)	Plants should come from within an approved propagation scheme and be certified pest-free following laboratory testing.
Chemical treatments on crops including reproductive material	*Used to mitigate likelihood of infestation of pests susceptible to chemical treatments* Several effective fungicides are available to control *F. brachygibbosum* as well as other species of *Fusarium*. Triazoles and strobilurins are effective in field treatment as well as when applied on reproductive material. In the case of cankers, chemical treatment may be difficult, as fungicides may fail to contact the target pathogen within woody tissues. Locally systemic fungicides may be applied in conjunction with pruning to protect high-value trees and shrubs. The possibility of selection of fungicide-resistant populations to triazoles and strobilurins has to be considered.

Special requirements summary (with hyperlink to information sheet if available)	Control measure summary in relation to *Fusarium brachygibbosum*
Roguing and pruning	*Used to mitigate likelihood of infestation by specified pest (usually a pathogen) at growing site where pest has limited dispersal* On some susceptible hosts, the infection by *F. brachygibbosum* may occur from conidia (micro- and macroconidia) formed on infected plants (e.g. cankers) or plant residues which can act as sources of inoculum. These propagules are dispersed from the infected organs and plant residues to newly established plants by rain splash, free water or high humidity. To reduce the sources of inoculum, pruning of the infected or damaged plant organs is highly recommended.
Inspections	*Used to mitigate likelihood of infestation by specified pest at origin* The symptoms commonly reported as incited by *F. brachygibbosum* (canker, crown rot, dieback, ear rot, root rot, wilting) are similar to those caused by many other fungal and bacterial pathogens. In some cases (see Stack et al., 2017), the pathogen has also been isolated from asymptomatic plant tissues. Therefore, it is unlikely that the pathogen could be detected based on visual inspection only.
Chemical treatments on consignments or during processing	*Used to mitigate likelihood of infestation of pests susceptible to chemical treatments* Triazoles and strobilurins are effective against *Fusarium* species, albeit no specific studies are available on the fungicide sensitivity of *F. brachygibbosum* and the effectiveness of their application.
Physical treatments on consignments or during processing	*Used to mitigate likelihood of infestation of pests susceptible to physical treatments* Removal of diseased plant organs (when applicable) could be adopted on consignment or during processing of symptomatic host plants to reduce the presence of *F. brachygibbosum*.
Controlled atmosphere	*Used to mitigate likelihood of infestation of pests susceptible to modified atmosphere (usually applied during transport) hence to mitigate entry* Modified and controlled atmosphere packages using polymeric films with different permeability for O_2, CO_2, other gases and H_2O can be used to maintain relative humidity, reduce water loss and contamination by different pathogens, including *F. brachygibbosum*, in various commodities.
Cleaning and disinfection of facilities, tools and machinery	*Used to mitigate likelihood of entry or spread of soil-borne pests* Phytosanitary measures to mitigate the risk of entry and spread of the pathogen on machinery and vehicles are included in CIR (EU) 2019/2072. Additional measures, such as cleaning, disinfection and disinfestation of tools and facilities (including premises, storage areas, etc.), may further mitigate the risk of entry or spread of *F. brachygibbosum*.
Conditions of transport	*Used to mitigate likelihood of entry of pests that could otherwise infest material post-production* When potentially infected/contaminated material has to be transported (including proper disposal of infested waste material), specific transport conditions (kind of packaging/protection, time of transport, transport mean) should be defined to prevent the pest from escaping (see Annex C Information sheet 1.15). These may include, albeit not exclusively: controlled atmosphere; physical protection; removal of leaves and peduncles from commodities; sealed packaging.
Phytosanitary certificate and plant passport	*Used to attest which of the above requirements have been applied* Recommended for plant species known as hosts of *F. brachygibbosum.*
Post-entry quarantine (PEQ) and other restrictions of movement in the importing country	*Plants in PEQ are held in conditions that prevent the escape of pests; they can be carefully inspected and tested to verify they are of sufficient plant health status to be released, or may be treated, re-exported or destroyed. Tests on plants are likely to include laboratory diagnostic assays and bioassays on indicator hosts to check whether the plant material is infected with particular pathogens* Recommended for plant species known as hosts of *F. brachygibbosum*.

3.6.1.1. Biological or technical factors limiting the effectiveness of measures to prevent the entry of the pest

- Latently infected plants and plant products are unlikely to be detected by visual inspection.
- The similarity of symptoms and signs caused by *F. brachygibbosum* with those caused by other *Fusarium* species makes it impossible to detect the pathogen based on symptomatology and morphology only.
- The lack of rapid diagnostic methods based on molecular approaches does not allow proper identification of the pathogen at entry. Thorough post-entry laboratory analyses may not be feasible for certain commodities as isolation in pure culture is needed prior to proceed with DNA extraction and molecular identification based on multigene sequencing.
- The broad host range of the pathogen limits the possibility to set standard diagnostic protocols for all potential hosts.
- The lack of studies on the sensitivity of *F. brachygibbosum* to existing fungicides and the effectiveness of their application may limit the design of proper control schemes.

3.7. Uncertainty

- Uncertainty exists about the actual range of host plants, since the pathogen was found on taxonomically different species and the number of new reports has flourished during the last five years.
- Uncertainty exists about the current distribution of *F. brachygibbosum* in the EU and worldwide, as in the past, when molecular tools (i.e. multilocus phylogenetic analysis) were not available, the fungus might have been misidentified as an FIESC or FCSC member based on morphology and pathogenicity tests.
- Uncertainty on the specific role of *F. brachygibbosum* in the aetiology of observed diseases in some of the reported hosts, since the pathogen has been often found in conjunction with other fungal species.
- Uncertainty on the real aggressiveness of *F. brachygibbosum* since pathogenicity tests have highlighted weak symptoms on some hosts.
- Uncertainty on the efficacy of the agricultural practices and disease control measures currently applied in the EU in reducing the impact of pest introduction.
- Uncertainty on the potential impact of the pathogen on some of the reported host crops grown in EU, due to the fact that no quantitative data are available.

4. Conclusions

F. brachygibbosum is present in the EU (Italy) with a restricted distribution. The pathogen satisfies the criteria that are within the remit of EFSA to assess for this species to be regarded as a potential Union quarantine pest. However, high uncertainty remains regarding the actual distribution of the pathogen in the EU and some uncertainty remains about its potential impact in the EU.

Table 7: 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 pathogen is well established and has been shown to be transmissible.	None
Absence/presence of the pest in the EU (Section 3.2)	*F. brachygibbosum* is reported from soil, sediment and seeds of quinoa and durum wheat in four regions in Italy. The status of this pest is currently under investigation by the competent authority.	Uncertainty exists about the current distribution of *F. brachygibbosum* in the EU, as in the past, when molecular tools were not available, the pathogen might have been identified as FIESC or FCSC based only on morphology and pathogenicity tests.

Criterion of pest categorisation	Panel's conclusions against criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest	Key uncertainties
Regulatory status (Section 3.3)	*F. brachygibbosum* is currently not regulated in the EU.	None.
Pest potential for entry, establishment and spread in the EU (Section 3.4)	The pathogen is able to enter into, become established in, and spread within, the EU territory. The main pathways for the entry of the pathogen into, and spread within, the EU territory are: (i) host plants for planting, (ii) seeds and (iii) soil and substrates associated or not with host plants. Spores of the pathogen may also be present as contaminants in other substrates (e.g. non-host plants, soils and substrates). Following establishment, *F. brachygibbosum* could spread within the EU territory by natural and human-assisted means. Trading of host plants for planting and seed is the main means of long-distance spread of the pathogen.	There is uncertainty about the host range of the pathogen.
Potential for consequences in the EU (Section 3.5)	The introduction of *F. brachygibbosum* is likely to have yield and quality impacts on some hosts (e.g. almond, onion, soybean and tobacco) that are grown in the EU, as well as environmental consequences in the EU territory.	There is uncertainty (i) about the potential impact of *F. brachygibbosum* on some of the reported hosts, and (ii) whether the agricultural practices (including chemical control) currently applied in the EU could reduce the impact caused by the pathogen.
Available measures (Section 3.6)	Yes. Although not specifically targeted against *F. brachygibbosum*, existing phytosanitary measures mitigate the likelihood of the pathogen's further entry into the EU territory. Potential additional measures also exist to further mitigate the risk of entry into, establishment within or spread of the pathogen within the EU.	None.
Conclusion (Section 4)	*F. brachygibbosum* meets all the criteria assessed by EFSA for consideration as a Union quarantine pest.	High uncertainty regarding the actual distribution of the pathogen in the EU and some uncertainty about its potential impact in the EU
Aspects of assessment to focus on/scenarios to address in future if appropriate:	The main knowledge gap concerns the need to ascertain the distribution of this pathogen within the EU territory. Given that all the data available in the literature have been explored, the Panel considers that specific surveys should be carried out and that *Fusarium* spp. isolates (particularly those previously ascribed to the FIESC or FCSC species complex based on morphology) from the EU present in culture collections should be re-evaluated using appropriate identification methods (i.e. multilocus gene sequencing analysis) to define the current geographical distribution of *F. brachygibbosum* in the EU territory.	

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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, 2018).
Control (of a pest)	Suppression, containment or eradication of a pest population (FAO, 2018).
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, 2018).
Eradication (of a pest)	Application of phytosanitary measures to eliminate a pest from an area (FAO, 2018).
Establishment (of a pest)	Perpetuation, for the foreseeable future, of a pest within an area after entry (FAO, 2018).
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.
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, 2018).
Pathway	Any means that allows the entry or spread of a pest (FAO, 2018).
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, 2018).
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, 2018).
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, 2018).

Appendix A – Distribution of *Fusarium brachygibbosum*

Distribution records based on CABI Crop Protection Compendium and additional literature.

Region	Country	Subnational (e.g. State)	Status
North America	Mexico	Hermosillo and Guaymas Valley (Sonora) Guanajuato Culiacan Valley (Sinaloa)	Present, no details Present, no details Present, no details Present, no details
	USA	California, Sutter County	Present, no details
		New Mexico	Present, no details
EU (27)	Italy	Lombardia (Pavia Province) Sicilia (Gela Province) Sardinia (Oristano Province; N39° 58′ 52′′ E8° 37′ 08′′) Molise (Campobasso Province; N 41° 33′ 48′′ E14° 39′ 49′′)	Present, no details Present, no details Present, no details Present, no details
Other Europe			No records
Africa	Algeria	Aïn Defla Province	Present, no details
	Morocco	El-Kdima (Taroudant)	Present, no details
	Tunisia	Kasserine Governorate	Present, no details
	South Africa	Kruger National Park; Willem Pretorius Game Reserve Lejweleputswa District Brits, North West Province	Present, no details Present, no details Present, no details
Asia	Azerbaijan	Kurdamir Province	Present, no details
	China	Xinxiang, Henan Province Heilongjiang Province Inner Mongolia Autonomous Region Jilin Province Xinjiang Uygur Autonomous Region Liaoning Province Mianchi, Lushi, Duguan, Lingbao, Sanmenxia Baiquan County, Heilongjiang Province	Present, no details Present, no details Present, no details Present, no details Present, no details Present, no details Present, no details Present, no details
	India	Parbhani, Hyderabad	Present, no details
	Iran	Ardabil Province Yazd Province Kerman Province Fars Province	Present, no details Present, no details Present, no details Present, no details
	Iraq	Al-Tewatha region Burjisia, Garma, Al-Hwuir (Basrah Province)	Present, no details Present, no details
	Malaysia	Penang	Present, no details
	Oman	Al-Sharqiya Al-Khoudh	Present, no details Present, no details
	Qatar	Undetermined	Present, no details
	Saudi Arabia	Bisha	Present, no details
	Turkey	Mersin	Present, no details
Oceania	Australia	Perth New South Wales	Present, no details Present, no details

Appendix B – *Fusarium brachygibbosum* host plants

Sources: EPPO Global Database (EPPO online), ARS/USDA Fungal Database, CFDA Pest Rating Database, Web of Science, Scopus, Google Scholar.

Host status	Host name	Plant family	Common name	Reference[A]
Cultivated hosts				
	Allium cepa	Amaryllidaceae	Onion	Tirado-Ramirez et al. (2021)
	Beta vulgaris	Amaranthaceae	Sugar beet	Cao et al. (2018)
	Cannabis sativa	Cannabaceae	Cannabis	Punja et al. (2018, 2019)
	Citrullus lanatus	Cucurbitaceae	Watermelon	Rentería-Martínez et al. (2015)
	Citrus limettioides	Rutaceae	Sweet lime	Al-Sadi et al. (2014)
	Citrus aurantium	Rutaceae	Sour orange	Ezrari et al. (2021)
	Euphorbia larica	Euphorbiaceae	Unknown	Al-Mahmooli et al. (2013)
	Fragaria × *ananassa*	Rosaceae	Strawberry	Mariscal-Amaro et al. (2017)
	Glycine max	Fabaceae	Soybean	Wang et al. (2021)
	Gossypium hirsutum	Malvaceae	Cotton	Le et al. (2020)
	Mentha piperita	Lamiaceae	Peppermint	Habibi et al. (2018)
	Nerium oleander	Apocynaceae	Oleander	Mirhosseini et al. (2014)
	Nicotiana tabacum	Solanaceae	Tobacco	Qiu et al. (2021)
	Olea europaea	Oleaceae	Olive	Trabelsi et al. (2017)
	Phoenix dactylifera	Arecaceae	Date palm	Al-Sadi et al. (2012), Saleh et al. (2017), Al-Nadabi et al. (2020), Namsi et al. (2020), Nishad and Ahmed, (2020), Rabaaoui et al. (2021)
	Prunus dulcis	Rosaceae	Almond	Seidle (2016), Stack et al. (2017)
	Sansevieria trifasciata	Asparagaceae	Snake plant	Kee et al. (2020)
	Solanum lycopersicum	Solanaceae	Tomato	Khamas et al. (2021)
	Solanum tuberosum	Solanaceae	Potato	Zimudzi et al. (2017), Azil et al. (2021)
	Sorghum vulgare	Poaceae	Sorghum	Padwick (1945)
	Trifolium subterraneum	Fabaceae	Subterranean clover	Tan et al. (2011)
	Triticum aestivum	Graminaceae	Wheat	Ali et al. (2020), Özer et al. (2020), Mohammed-Ameen et al. (2021)
	Triticum sp.	Graminaceae	Wheat	Van Coller et al. (2013)
	Vitis vinifera	Vitaceae	Grapevine	Akgül and Ahioğlu (2019)
	Zea mays	Poaceae	Corn, maize	Shan et al. (2017), Fallahi et al. (2019)
Wild weed hosts	*Orobanche cumana*	Orobanchaceae	Sunflower broomrape	Xia et al. (2018)
	Stipa tenacissima	Poaceae	Mediterranean perennial alfa grass	Gargouri et al. (2018)
Artificial/ experimental host				

Appendix C – EU 27 annual imports of fresh produce of hosts from countries where *Fusarium brachygibbosum* is present, 2016–2020 (in 100 kg)

Source EUROSTAT (accessed 19/7/2021)

		2016	2017	2018	2019	2020
Fresh or chilled onions and shallots	Mexico	28,762.91	33,752.53	44,750.38	26,157.27	50,587.04
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)	1,987.72	1,142.55	2,318.00	40,531.14	595.11
	Algeria	203.40	450.07	1,230.87	5,053.02	1,093.10
	Morocco	37,000.62	30,165.86	49,783.64	40,690.08	45,353.98
	Tunisia	42.63	129.10	5,421.20	525.20	39.76
	South Africa (incl. Namibia 'NA' to 1989)	1,476.16	3,216.17	238.28	39,631.68	732.36
			0.00			
	Azerbaijan		0.00	25,100.05	11,364.90	1,316.00
	China	1,570.06	4,184.73	39,652.78	192,208.27	11,208.92
	India	173,643.95	124,553.15	117,956.65	357,836.53	127,654.61
	Iran, Islamic Republic of	2.79	0.65	11,516.94	14,989.32	215.52
	Iraq					
	Malaysia	29.02	75.22	2.62	2.85	3.82
	Oman		0.00			
	Qatar		0.00			260.00
	Saudi Arabia		0.00			
	Turkey	160,989.30	41,570.59	71,903.13	291,949.96	134,621.17
	Australia	200,590.73	78,169.50	72,814.46	139,723.55	132,718.35
	Total	606,299.29	317,410.12	442,689.00	1,160,663.77	506,399.74

		2016	2017	2018	2019	2020
Sugar beet, fresh, chilled, frozen or dried	Mexico	0.00	0.12			
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)	0.47	0.33	0.08	0.00	0.01
	Algeria					
	Morocco					
	Tunisia					
	South Africa (incl. Namibia 'NA' to 1989)					
	Azerbaijan					
	China	45.10	2.00	0.00		
	India	1,072.71			0.02	
	Iran, Islamic Republic of					
	Iraq					
	Malaysia					0.02
	Oman					
	Qatar					
	Saudi Arabia					
	Turkey	2.92		2.64	1.87	
	Australia					
	Total	1,121.20	2.45	2.72	1.89	0.03

		2016	2017	2018	2019	2020
Live perennial outdoor plants incl. their root	Mexico	520.00	964.44	415.80	964.44	520.00
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)	2,221.32	2,476.93	1,887.84	2,476.93	2,221.32
	Algeria					
	Morocco	874.88	49.12	248.36	49.12	874.88
	Tunisia	1,461.15	2,241.70	2,157.00	2,241.70	1,461.15
	South Africa (incl. Namibia 'NA' to 1989)	20.84	19.86	11.98	19.86	20.84
	Azerbaijan					
	China	2,008.78	1,820.48	1,757.70	1,820.48	2,008.78
	India	34.54	350.65	508.69	350.65	34.54
	Iran, Islamic Republic of					
	Iraq					
	Malaysia		0.00	0.04	0.00	
	Oman		0.00		0.00	
	Qatar	369.52				369.52
	Saudi Arabia		0.00		0.00	
	Turkey	4,001.04	4,494.07	2,774.75	4,494.07	4,001.04
	Australia	501.98	3.06	948.13	3.06	501.98
	Total	12,014.05	12,420.31	10,710.29	12,420.31	12,014.05

		2016	2017	2018	2019	2020
Soya beans, whether or not broken	Mexico	0.33	0.03	0.14	13.34	191.16
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)	52,881,397.81	46,059,027.06	73,716,535.24	67,208,322.53	48,475,225.61
	Algeria		0.00			
	Morocco		250.00	35.00	5.61	19.70
	Tunisia		0.00			
	South Africa (incl. Namibia 'NA' to 1989)	55.62	7.82	19.60	5.36	0.08
			0.00			
	Azerbaijan		0.00			
	China	217,569.88	275,802.32	375,025.50	377,466.32	146,355.78
	India	190,850.85	3,813,40.48	227,637.85	219,336.14	144,164.06
	Iran, Islamic Republic of	62.73	123.14	152.64	266.21	382.28
	Iraq		0.00			
	Malaysia		4.40	2.43	0.09	0.16
	Oman		0.00			
	Qatar		0.00			
	Saudi Arabia	20.25	0.10			
	Turkey	119,198.80	35,287.90	61,000.06	224.02	0.00
	Australia		1,224.16	0.16	228.75	0.02
	Total	53,409,156.27	46,753,067.41	74,380,408.62	67,805,868.37	48,766,338.85

		2016	2017	2018	2019	2020
Fresh or dried almonds in shell	Mexico		0.00		0.06	0.16
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)	18,915.75	41,830.25	20,010.65	25,694.76	24,277.03
	Algeria					
	Morocco		2,484.03	792.01	25.01	
	Tunisia	1,931.71	1,806.90	1,188.97	1,886.23	1,788.88
	South Africa (incl. Namibia 'NA' to 1989)		0.00		0.00	
			0.00			
	Azerbaijan					
	China		198.00	2.52	2.35	0.46
	India	3.29	2.31	0.36	0.40	0.21
	Iran, Islamic Republic of	15.86	17.41	13.17	6.92	1.69
	Iraq				0.10	
	Malaysia		0.00			
	Oman					
	Qatar					
	Saudi Arabia	0.67	2.00			
	Turkey	1,352.00	1,327.90	1,682.57	1,474.83	2,678.62
	Australia	266.71	1,649.05	512.57	2.89	217.76
	Total	22,485.99	49,317.85	24,202.82	29,093.55	28,964.81

		2016	2017	2018	2019	2020
Fresh or dried almonds, shelled	Mexico		0.00			0.04
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)	2,230,239.74	2,282,243.12	2,365,462.97	2,353,495.20	2,586,252.96
	Algeria			0.00	88.00	1.93
	Morocco	11,691.89	8,400.15	9,228.27	10,034.49	10,656.78
	Tunisia	482.44	215.54	669.46	343.79	760.73
	South Africa (incl. Namibia 'NA' to 1989)	0.00	40.96	232.79	1.00	706.50
			0.00			
	Azerbaijan		0.00			
	China	21.05	634.94	1,569.61	957.12	1,423.73
	India	11.80	13.03	0.18	0.37	1.80
	Iran, Islamic Republic of	33.98	42.35	1,951.32	1,200.25	680.16
	Iraq			2.79		10.60
	Malaysia	0.00	170.00			
	Oman		0.00			
	Qatar		0.00			
	Saudi Arabia	0.20	0.00	0.00	0.75	0.45
	Turkey	1,778.83	1,432.56	1,746.68	1,072.06	1,236.39
	Australia	215,519.33	209,919.76	165,421.49	126,999.33	142,682.44
	Total	2,459,779.26	2,503,112.41	2,546,285.56	2,494,192.36	2,744,414.51

		2016	2017	2018	2019	2020
Potatoes, fresh or chilled	Mexico	0.05	0.00		0.14	1.04
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)	1.53	62.76	10.88	60.62	37.07
	Algeria	5,612.00	2,489.60	5,089.34	6,643.02	9,440.93
	Morocco	131,711.64	110,097.90	39,314.23	369,410.02	105,090.48
	Tunisia	10,161.26	8,790.21	8,323.20	12,047.91	10,555.79
	South Africa (incl. Namibia 'NA' to 1989)	2.00	0.00		235.95	
			0.00			
	Azerbaijan		0.00			
	China	0.09	5.00			0.43
	India	0.01	0.00			
	Iran, Islamic Republic of		0.00			
	Iraq					
	Malaysia		0.00			
	Oman		0.00			
	Qatar		0.00			
	Saudi Arabia		1,300.00	2,630.00	1,085.00	
	Turkey	53,965.03	58,461.50	5,076.59	12,070.55	10,052.44
	Australia		0.00			
	Total	201,453.61	181,206.97	60,444.24	401,553.21	135,178.18

		2016	2017	2018	2019	2020
Grain sorghum	Mexico	6.94	7.74	26.86	16.02	5.57
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)	15,168.59	10,835.83	5,204,254.29	4,181,234.30	20,396.59
	Algeria					
	Morocco	31.00	17.86	44.05	23.00	96.88
	Tunisia			20.16	20.18	
	South Africa (incl. Namibia 'NA' to 1989)		226.72	766.98	1,119.51	440.20
	Azerbaijan					
	China	157.77	224.30	206.49	263.47	533.57
	India	8,819.18	574.07	8,000.25	1,262.75	543.18
	Iran, Islamic Republic of	0.00				
	Iraq					
	Malaysia					
	Oman					
	Qatar					
	Saudi Arabia					0.20
	Turkey				340.00	4.00
	Australia	3,665.50	1,667.28	3,694.90	2,263.98	1,978.50
	Total	27,848.98	13,553.80	5,217,013.98	4,186,543.21	23,998.69

		2016	2017	2018	2019	2020
Bulbs, tubers, tuberous roots, corms, crowns and rhizomes	Mexico	30.31	0.10	1.42	2.08	0.20
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)	1,769.63	1,287.01	689.01	522.77	216.17
	Algeria					
	Morocco	314.14	180.41	724.97	311.53	217.86
	Tunisia					
	South Africa (incl. Namibia 'NA' to 1989)	5,902.59	6,269.15	6,051.16	5,794.12	5,675.36
						0.44
	Azerbaijan					
	China	2,697.53	2,707.89	2,569.21	2,597.30	2,068.84
	India	724.25	490.40	2,126.53	1,582.15	2,703.35
	Iran, Islamic Republic of		0.00			
	Iraq					
	Malaysia	7.55	14.60	9.23	2.62	0.17
	Oman					
	Qatar					
	Saudi Arabia	0.00				
	Turkey	735.27	1,121.03	1,556.26	1,987.00	3,065.21
	Australia	186.30	90.06	5,324.71	4,765.24	3,761.28
	Total	12,367.57	12,160.65	19,052.50	17,564.81	17,708.88
		2016	**2017**	**2018**	**2019**	**2020**
Wheat and meslin	Mexico	1,959,739.74	137,501.43	2.04	352,707.52	230,003.29
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)	6,710,478.26	4,576,798.42	5,743,028.31	7,779,082.40	9,740,873.51
	Algeria	12.00	10.00	60.00		
	Morocco		2,550.00	1.80	503.30	0.36
	Tunisia		0.00	0.50	0.16	
	South Africa (incl. Namibia 'NA' to 1989)		0.00			4.32
			0.00			
	Azerbaijan		0.00			
	China	2,075.29	794.35	423.87	466.87	467.00
	India	410.93	3,995.94	1,981.39	10,114.79	7,317.88
	Iran, Islamic Republic of	43.16	288,189.28	8.16	19.44	117.00
	Iraq					
	Malaysia		0.00	0.01	0.01	
	Oman		0.00			
	Qatar		0.00			
	Saudi Arabia		0.00		0.05	
	Turkey	685.40	374,932.78	188,683.88	297,853.39	839,770.57
	Australia	1,284,126.20	2,449,536.29	1,628,585.53	1.65	411.67
	Total	9,957,570.98	7,834,308.49	7,562,775.49	8,440,749.58	10,818,965.60

		2016	2017	2018	2019	2020
Vine slips, grafted or rooted	Mexico					
	United States (incl. Navassa Island (part of 'UM') from 1995 to 2000)		0.06	0.01		0.01
	Algeria					
	Morocco				120.00	
	Tunisia					
	South Africa (incl. Namibia 'NA' to 1989)					
	Azerbaijan					
	China					
	India					
	Iran, Islamic Republic of					
	Iraq					
	Malaysia					
	Oman					
	Qatar					
	Saudi Arabia					
	Turkey		8.03			
	Australia					2.99
	Total	0.00	8.09	0.01	120.00	3.00

Appendix D – EU 27 and member state cultivation/harvested/production area of Colletotrichum fructicola hosts (in 1,000 ha)

Source EUROSTAT (accessed 19/7/2021)

Wheat and spelt	2016	2017	2018	2019	2020
EU 27	25,210.30	24,138.62	23,751.66	24,210.19	22,802.51
Belgium	215.72	197.59	195.69	203.76	195.00
Bulgaria	1,192.59	1,144.52	1,212.01	1,198.68	1,200.40
Czechia	839.71	832.06	819.69	839.45	798.58
Denmark	583.00	586.60	425.80	573.40	502.60
Germany	3,201.70	3,202.60	3,036.30	3,118.10	2,835.50
Estonia	164.50	169.75	154.58	166.98	168.04
Ireland	67.92	67.05	57.98	63.48	46.41
Greece	537.59	415.95	404.49	350.49	331.73
Spain	2,256.85	2,062.71	2,063.68	1,920.09	1,909.52
France	5,542.25	5,332.08	5,234.09	5,244.25	4,513.52
Croatia	171.40	118.38	138.46	143.15	145.70
Italy	1,912.42	1,806.57	1,821.73	1,754.64	1,711.22
Cyprus	8.39	8.68	10.20	10.59	12.50
Latvia	479.10	446.80	417.20	492.70	498.20
Lithuania	880.53	811.95	772.89	895.76	891.57
Luxembourg	13.81	14.11	12.87	13.36	11.93
Hungary	1,044.31	966.40	1,026.15	1,015.64	933.46
Malta	0.00	0.00	0.00	0.00	0.00
Netherlands	127.33	115.92	111.66	120.55	108.91
Austria	317.76	297.28	294.29	278.34	279.02
Poland	2,364.08	2,391.85	2,417.23	2,511.33	2,471.55
Portugal	38.20	29.02	27.03	26.44	28.04
Romania	2,137.73	2,052.92	2,116.15	2,168.37	2,145.58
Slovenia	31.46	28.02	27.82	26.73	27.27
Slovakia	417.71	373.67	403.37	406.82	387.08
Finland	215.10	194.28	177.80	197.60	198.80
Sweden	449.15	471.87	372.50	469.49	450.39

Sorghum	2016	2017	2018	2019	2020
EU 27	123.77	135.66	147.85	190.32	226.84
Belgium	0.00	0.00	0.00	0.00	0.00
Bulgaria	3.29	4.24	8.86	7.04	2.60
Czechia	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00
Germany	0.30	:	:	:	:
Estonia	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00
Greece	2.74	3.01	2.62	2.36	2.32
Spain	8.12	6.96	5.97	6.56	5.70
France	48.46	56.24	60.77	83.09	116.68
Croatia	0.06	0.00	0.00	0.00	0.00
Italy	43.84	40.90	39.60	46.80	52.91
Cyprus	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00

Sorghum	2016	2017	2018	2019	2020
Hungary	4.45	6.25	9.62	23.32	26.06
Malta	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.00	0.00	0.00	0.00
Austria	2.26	2.99	3.53	3.94	4.64
Poland	0.00	0.00	0.00	0.00	0.00
Portugal	0.00	0.00	0.00	0.00	0.00
Romania	9.16	13.99	15.93	15.71	14.17
Slovenia	0.11	0.14	0.08	0.13	0.09
Slovakia	0.97	0.64	0.57	1.07	1.36
Finland	0.00	0.00	0.00	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00
Soya	**2016**	**2017**	**2018**	**2019**	**2020**
EU 27	831.18	962.39	955.40	907.91	939.80
Belgium	0.00	0.00	0.00	0.00	0.00
Bulgaria	14.16	11.53	2.32	3.86	4.50
Czechia	10.61	15.34	15.23	12.24	14.15
Denmark	0.00	0.00	0.00	0.00	0.00
Germany	15.80	19.10	24.10	28.90	33.80
Estonia	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00
Greece	1.55	1.46	0.61	1.03	0.80
Spain	1.00	1.69	1.48	1.57	1.41
France	136.52	141.83	153.85	163.80	186.95
Croatia	78.61	85.13	77.09	78.33	86.30
Italy	288.06	322.42	326.59	273.33	256.13
Cyprus	0.00	0.00	0.00	0.00	0.00
Latvia	0.00	0.00	0.00	0.00	0.00
Lithuania	1.85	2.47	1.92	1.82	2.07
Luxembourg	0.00	0.00	0.00	0.00	0.00
Hungary	61.03	75.67	62.12	58.23	59.16
Malta	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.00	0.54	0.48	0.00
Austria	49.79	64.47	67.62	69.21	68.50
Poland	7.60	9.33	5.45	7.92	7.87
Portugal	0.00	0.00	0.00	0.00	0.00
Romania	127.27	165.14	169.42	158.15	165.46
Slovenia	2.47	2.91	1.76	1.43	1.64
Slovakia	34.87	43.90	45.30	47.60	51.07
Finland	0.00	0.00	0.00	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00
Watermelons	**2016**	**2017**	**2018**	**2019**	**2020**
EU 27	75.29	76.47	73.54	74.57	:
Belgium	0.00	0.00	0.00	0.00	0.00
Bulgaria	4.74	4.82	4.32	4.78	4.42
Czechia	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00
Germany	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00

Watermelons	**2016**	**2017**	**2018**	**2019**	**2020**
Greece	10.76	11.13	9.62	8.82	11.28
Spain	19.16	20.03	20.40	21.46	21.62
France	0.91	0.93	0.94	0.64	1.01
Croatia	0.68	0.68	0.97	0.67	0.52
Italy	12.01	12.84	12.97	13.73	13.45
Cyprus	0.47	0.44	0.43	0.42	0.39
Latvia	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00
Hungary	5.41	5.27	5.09	5.12	4.20
Malta	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.00	0.00	0.00	0.00
Austria	0.00	0.00	0.00	0.03	0.04
Poland	0.00	0.00	0.00	0.00	:
Portugal	1.11	1.11	0.93	0.93	0.55
Romania	19.90	19.09	17.80	17.86	16.16
Slovenia	0.02	0.01	0.01	0.02	0.02
Slovakia	0.14	0.12	0.06	0.09	0.09
Finland	0.00	0.00	0.00	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00
Onions	**2016**	**2017**	**2018**	**2019**	**2020**
EU 27	169.93	170.68	171.78	176.63	176.29
Belgium	2.96	3.77	4.28	4.42	4.80
Bulgaria	1.37	2.08	3.68	2.63	2.62
Czechia	1.55	1.70	1.66	1.76	1.78
Denmark	1.47	1.44	1.30	1.33	1.37
Germany	13.56	14.07	13.58	14.39	14.73
Estonia	0.02	0.03	0.02	0.03	0.03
Ireland	0.21	0.19	0.17	0.29	0.22
Greece	5.92	5.54	4.43	3.81	5.65
Spain	25.74	25.46	24.39	26.52	25.32
France	13.08	12.50	12.66	14.65	14.85
Croatia	0.91	0.80	0.80	0.79	0.59
Italy	12.71	12.25	15.19	14.06	12.82
Cyprus	0.17	0.14	0.13	0.15	0.14
Latvia	0.30	0.40	0.50	0.37	0.50
Lithuania	1.58	1.42	1.57	1.62	1.71
Luxembourg	0.01	0.02	0.02	0.03	0.03
Hungary	2.20	2.01	1.55	1.67	1.63
Malta	0.00	0.00	0.00	0.00	0.00
Netherlands	32.72	34.36	34.51	36.51	35.94
Austria	3.51	3.54	3.30	3.51	3.41
Poland	26.98	26.65	25.45	25.20	25.30
Portugal	1.95	1.69	1.52	1.52	1.90
Romania	17.26	17.04	17.29	17.35	16.85
Slovenia	0.45	0.44	0.43	0.45	0.49
Slovakia	0.85	0.70	0.88	1.06	1.07
Finland	1.13	1.20	1.26	1.24	1.23
Sweden	1.33	1.26	1.22	1.28	1.31

Shallots	2016	2017	2018	2019	2020
EU 27	:	:	:	:	:
Belgium	0.00	0.00	0.00	0.00	0.00
Bulgaria	0.00	0.00	0.00	0.00	0.00
Czechia	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00
Germany	:	:	:	:	:
Estonia	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00
Greece	0.00	0.00	0.00	0.00	0.00
Spain	0.00	0.00	0.00	0.00	0.01
France	2.46	2.34	2.35	2.37	2.28
Croatia	0.00	0.00	0.00	0.00	0.00
Italy	0.00	0.00	0.00	0.00	0.00
Cyprus	0.00	0.00	0.00	0.00	0.00
Latvia	:	:	:	:	:
Lithuania	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00
Hungary	0.00	0.00	0.00	0.00	0.00
Malta	0.00	0.00	0.00	0.00	0.00
Netherlands	:	:	:	:	:
Austria	0.00	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00	0.10
Portugal	0.00	0.03	0.01	0.01	0.00
Romania	0.00	0.00	0.00	0.00	0.00
Slovenia	0.03	0.03	0.03	0.03	0.04
Slovakia	0.00	0.00	:	:	:
Finland	0.00	0.00	0.00	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00

Beetroot	2016	2017	2018	2019	2020
EU 27	23.38	23.51	24.25	25.12	24.88
Belgium	0.00	0.05	0.04	0.04	0.00
Bulgaria	0.11	0.10	0.04	0.05	0.04
Czechia	0.00	0.00	0.14	0.20	0.21
Denmark	0.28	0.27	0.28	0.30	0.32
Germany	1.67	1.74	1.83	1.91	2.09
Estonia	0.24	0.25	0.21	0.21	0.16
Ireland	0.00	0.00	0.00	0.00	0.00
Greece	0.55	0.58	0.59	0.50	0.58
Spain	1.31	1.13	1.16	1.26	1.16
France	3.03	3.12	3.10	3.14	2.88
Croatia	0.14	0.14	0.18	0.16	0.15
Italy	0.85	0.88	0.87	0.84	0.70
Cyprus	0.03	0.03	0.03	0.03	0.03
Latvia	0.40	0.20	0.30	0.36	0.30
Lithuania	1.84	1.76	2.09	2.35	2.20
Luxembourg	0.01	0.01	0.01	0.00	0.01
Hungary	0.38	0.33	0.31	0.28	0.25
Malta	0.00	0.00	0.00	0.00	0.00
Netherlands	0.74	0.95	0.88	0.87	0.86

Beetroot	2016	2017	2018	2019	2020
Austria	0.15	0.15	0.14	0.15	0.15
Poland	10.24	10.37	10.55	10.70	11.30
Portugal	0.17	0.14	0.22	0.22	0.16
Romania	0.16	0.15	0.15	0.24	0.14
Slovenia	0.17	0.16	0.16	0.21	0.23
Slovakia	0.07	0.09	0.04	0.13	0.12
Finland	0.43	0.42	0.46	0.47	0.38
Sweden	0.44	0.50	0.49	0.51	0.48
Citrus fruit	**2016**	**2017**	**2018**	**2019**	**2020**
EU 27	519.01	502.84	508.99	512.53	487.08
Belgium	0.00	0.00	0.00	0.00	0.00
Bulgaria	0.00	0.00	0.00	0.00	0.00
Czechia	0.00	0.00	0.00	0.00	0.00
Denmark	0.00	0.00	0.00	0.00	0.00
Germany	0.00	0.00	0.00	0.00	0.00
Estonia	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00
Greece	45.86	43.47	46.26	44.23	44.48
Spain	295.33	294.26	297.62	296.48	297.97
France	4.22	4.27	4.39	4.61	4.69
Croatia	2.19	2.06	1.97	2.20	2.04
Italy	147.65	135.36	134.64	140.74	113.80
Cyprus	3.41	2.92	3.05	3.20	3.04
Latvia	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00
Luxembourg	0.00	0.00	0.00	0.00	0.00
Hungary	0.00	0.00	0.00	0.00	0.00
Malta	0.00	0.00	0.00	0.00	0.00
Netherlands	0.00	0.00	0.00	0.00	0.00
Austria	0.00	0.00	0.00	0.00	0.00
Poland	0.00	0.00	0.00	0.00	0.00
Portugal	20.36	20.51	21.07	21.07	21.07
Romania	0.00	0.00	0.00	0.00	0.00
Slovenia	0.00	0.00	0.00	0.00	0.00
Slovakia	0.00	0.00	0.00	0.00	0.00
Finland	0.00	0.00	0.00	0.00	0.00
Sweden	0.00	0.00	0.00	0.00	0.00
Grapes	**2016**	**2017**	**2018**	**2019**	**2020**
EU 27	3,136.04	3,134.93	3,137.17	3,160.68	3,162.48
Belgium	0.24	0.24	0.30	0.38	0.49
Bulgaria	36.55	34.11	34.11	30.05	28.81
Czechia	15.80	15.81	15.94	16.08	16.14
Denmark	0.00	0.00	0.00	0.00	0.00
Germany	:	:	:	:	:
Estonia	0.00	0.00	0.00	0.00	0.00
Ireland	0.00	0.00	0.00	0.00	0.00
Greece	98.09	101.75	100.34	101.85	101.85
Spain	935.11	937.76	939.92	936.89	931.96
France	751.69	750.46	750.62	755.47	758.86

Grapes	2016	2017	2018	2019	2020
Croatia	23.40	21.90	20.51	19.82	20.63
Italy	673.76	670.09	675.82	697.91	703.90
Cyprus	6.07	5.93	6.67	6.67	6.79
Latvia	0.00	0.00	0.00	0.00	0.00
Lithuania	0.00	0.00	0.00	0.00	0.00
Luxembourg	1.26	1.26	1.25	1.24	1.24
Hungary	68.12	67.08	66.06	64.92	62.90
Malta	0.68	0.68	0.42	0.42	0.42
Netherlands	0.14	0.16	0.17	0.16	0.17
Austria	46.49	48.05	48.65	48.72	48.06
Poland	0.62	0.67	0.73	0.74	0.76
Portugal	179.05	178.84	178.78	178.78	178.78
Romania	174.17	175.32	172.80	176.34	176.76
Slovenia	15.84	15.86	15.65	15.57	15.29
Slovakia	8.71	8.47	8.01	7.92	7.73
Finland	0.00	0.00	0.00	0.00	0.00
Sweden	0.05	0.04	0.05	0.05	0.06