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Pest categorisation of *Coleosporium asterum*, *C. montanum* and *C. solidaginis*

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Abstract

The EFSA Plant Health Panel performed a pest categorisation of *Coleosporium asterum* (Dietel) Sydow & P. Sydow, *Coleosporium montanum* (Arthur & F. Kern) and *Coleosporium solidaginis* (Schwein.) Thüm, three basidiomycete fungi belonging to the family Coleosporiaceae, causing rust diseases on *Pinus* spp. (aecial hosts) and on Asteraceae (telial hosts). *Coleosporium asterum* was described on *Aster* spp. in Japan and has been reported from China, Korea, France and Portugal. *Coleosporium montanum* is native to North America, has been introduced to Asia and has been reported from Austria on *Symphyotrichum* spp. *Coleosporium solidaginis* has been reported on *Solidago* spp. from North America, Asia and Europe (Switzerland and Germany). There is a key uncertainty about these reported distributions, due to the until recently accepted synonymy between these fungi and the lack of molecular studies. The pathogens are not listed in Annex II of Commission Implementing Regulation (EU) 2019/2072, an implementing act of Regulation (EU) 2016/2031, or in any emergency plant health legislation. There are no reports of interceptions of *C. asterum, C. montanum* or *C. solidaginis* in the EU. The pathogens can further enter into, establish in and spread within the EU via host plants for planting, other than seeds and host plant parts (e.g. cut flowers, foliage, branches), other than fruits. Entry into and spread within the EU may also occur by natural means. Host availability and climate suitability in the EU are favourable for the establishment of the pathogens in areas where host plants in the Asteraceae and Pinaceae co-exist. Impacts can be expected on both aecial and telial hosts. Phytosanitary measures are available to reduce the risk of further introduction and spread of the three pathogens in the EU. *Coleosporium asterum, C. montanum* and *C. solidaginis* satisfy the criteria that are within the remit of EFSA to assess for these species to be regarded as Union quarantine pests, but a key uncertainty exists about their EU distribution.

Keywords: Aster rust, needle cast of red pine, pest risk, plant health, plant pest, Solidago/goldenrod rust, Western pine-aster rust

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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

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

There is uncertainty about the synonymy reported in Index Fungorum (https://www.speciesfungorum.org/Names/SynSpecies.asp?RecordID=119921) between *C. asterum, C. montanum* and *C. solidaginis* (see Section 3.1.1). In the past, these fungi were synonymised but they are now recognised as genetically distinct species of fungal plant pathogens (Beenken et al., 2017; McTaggart and Aime, 2018; Scheck, 2020a,b). Therefore, this pest categorisation considers them as separate entities.

1.3. Additional information

The pest categorisation was initiated following the commodity risk assessment of black pine (*Pinus thunbergii* Parl.) bonsai from Japan and China (EFSA PLH Panel, 2019, 2022).

2. Data and methodologies

2.1. Data

2.1.1. Information on pest status from NPPOs

In the context of the current mandate, EFSA is preparing pest categorisations for new/emerging pests that are not yet regulated in the EU. When official pest status is not available in the European and Mediterranean Plant Protection Organization (EPPO) Global Database (EPPO, online), EFSA consults the NPPOs of the relevant MSs. To obtain information on the official pest status for *C. asterum*, EFSA has consulted the NPPOs of France, Germany, Portugal and Spain in February 2023. The results of this consultation are presented in Section 3.2.2.

2.1.2. Literature search

A literature search on *C. asterum, C. montanum* and *C. solidaginis* was conducted at the beginning of the categorisation (March 2023) in the ISI Web of Science bibliographic database, using the scientific name of the pests as search term. Papers relevant for the pest categorisation were reviewed, and further references and information were obtained from experts, as well as from citations within the references and grey literature.

2.1.3. Database search

Pest information, on host(s) and distribution, was retrieved from the European and Mediterranean Plant Protection Organization (EPPO) Global Database (EPPO, online), the CABI databases and scientific literature databases as referred above in Section 2.1.1.

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

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

2.2. Methodologies

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

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

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

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

Criterion of pest categorisation	Criterion in Regulation (EU) 2016/2031 regarding Union quarantine pest (article 3)
Identity of the pest (Section 3.1)	Is the identity of the pest clearly defined, or has it been shown to produce consistent symptoms and to be transmissible?
Absence/presence of the pest in the EU territory (Section 3.2)	Is the pest present in the EU territory? If present, is the pest in a limited part of the EU or is it scarce, irregular, isolated or present infrequently? If so, the pest is considered to be not widely distributed.
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 for entry and spread.
Potential for consequences in the EU territory (Section 3.5)	Would the pests' introduction have an economic or environmental impact on the EU territory?
Available measures (Section 3.6)	Are there measures available to prevent pest entry, establishment, spread or impacts? If already present in the EU are measures available to slow spread or facilitate eradication?
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 pests

3.1.1. Identity and taxonomy

Is the identity of the pest clearly defined, or has it been shown to produce consistent symptoms and/or to be transmissible? (Yes or No)

Yes, the identities of *Coleosporium asterum, C. montanum* and *C. solidaginis* are clearly defined, and the pathogens have been shown to produce consistent rust symptoms and to be transmissible.

Coleosporium asterum (Dietel) Sydow & P. Sydow., *Coleosporium montanum* (Arthur & F. Kern) and *Coleosporium solidaginis* (Schwein.) Thüm are plant pathogenic fungi of the family *Coleosporiaceae* (Pucciniales, Pucciniomycotina) (Raabe and Pyeatt, 1990; McTaggart and Aime, 2018). The genus *Coleosporium* includes ~ 100 accepted species of heteroecious, usually macrocyclic rust fungi (Kirk et al., 2008). The spermogonial and aecial stages of *Coleosporium* spp. cause needle rust on *Pinus* spp., whereas the uredinial and telial stages infect hosts belonging to several species in the family Asteraceae (=Compositae) (Cummins and Hiratsuka, 2003).

The uredinial stage of *C. solidaginis* was first described as *Uredo solidaginis* by Ludwig D. von Schweinitz in 1882 (Schweinitz, 1882) from a mixed specimen on species of *Aster*, *Solidago* and *Vernonia* in the USA. Felix von Thümen (1878) described a telial stage on two species of *Solidago* in New Jersey, renaming the pathogen as *Coleosporium solidaginis*. The aecial stage was described on *Pinus rigida* as *Peridermium acicolum* (Underwood and Earle, 1896), and later confirmed as the aecial stage of *C. solidaginis* by Clinton (1907).

Arthur and Kern (1906) described a new rust on *Pinus contorta* (lodgepole pine), naming it *Peridermium montanum*. Hedgcock (1912) detected a rust fungus on *Aster* spp. plants growing near the same lodgepole pine trees and considered it as the same species (i.e. *P. montanum*) previously described on *P. contorta* by Arthur and Kern (1906). Hedgcock (1916) achieved infection of *Aster* sp. upon inoculation with aeciospores collected from lodgepole pine and inferred that the two species names, *P. montanum* and *P. acicolum,* defined the same organism, which he considered to be *Coleosporium solidaginis*.

This hypothesis was confirmed by Weir and Hubert (1916), who achieved successful infection of both *Solidago* and *Aster* species with a genotype of *P. montanum*. Later, Hedgcock and Hunt (1922a,b) failed in infecting *Aster* spp. and *Callistephus chinensis* (China aster) with *C. solidaginis*, whereas infection of 142 species of *Solidago* over a total of 241 tested was successful. This result led them to hypothesise that either there were two pathotypes of *C. solidaginis*, or that the *Coleosporium* sp. infecting *Aster* spp. was a different species. A similar hypothesis was also formulated by Weir (1925), while Nicholls et al. (1968) reported three pathotypes of the pine rust fungus based on differential infection of *Solidago* and *Aster* spp., and possibly *C. chinensis* (however, neither the genus nor the species of the annual asters used are mentioned in their paper).

In North America, between 21 (Cummins, 1978) and 27 (Farr and Rossman, 2018) species of *Coleosporium* were reported to infect Asteraceae, but only two species, i.e. *C. asterum* and *C. solidaginis*, were described on *Solidago* by Arthur (1934) and by Cummins (1962): the first considered *C. asterum* as a synonym of *C. solidaginis*, whereas Cummins (1962) treated *C. solidaginis* as a synonym of *C. asterum,* because *C. solidaginis* was described only based on uredinia (telial stage). Apparently, these authors considered *C. asterum* and *C. solidaginis* to be conspecific. According to the general rule in fungal taxonomy, since *U. solidaginis* is the oldest valid description of the fungus (Schweinitz, 1882), the name *C. solidaginis* should have priority over *C. asterum* if these are to be considered the same species. Recent DNA barcoding-based phylogenetic analyses carried out by Beenken et al. (2017) showed that *C. solidaginis* and *C. asterum* are not conspecific: therefore, the *Coleosporium* species causing rust on *Solidago* species should be named as *C. solidaginis* (Beenken et al., 2017).

Dietel (1899) first described a rust on *C. chinensis* in Japan (without mentioning the aecial host) naming it *Stichopsora asterum*. Sydow and Sydow (1914) later changed this name to *C. asterum*. Reporting on the pine needle rusts of Japan, Kaneko (1981) proposed that the correct name of the fungus on *C. chinensis* in Japan should be *Coleosporium pini-asteris* Orish., which differs from the *Coleosporium* infecting *C. chinensis* in North America. In addition, Kaneko (1981) compared specimens of *C. asterum* from *Aster* and *Solidago* spp. from eastern and western North America with those isolated in Japan (including the type specimen of *C. asterum*) and concluded that material referred to as '*C. asterum*' from North America includes two separate species, as earlier hypothesised by Hedgcock and Hunt (1922a, 1922b), that are different from *C. asterum* and *C. pini-asteris* from Japan.

More recently, McTaggart and Aime (2018) conducted a systematic study on ca. 60 specimens of *Coleosporium* infecting species of Asteraceae from North America based on a combination of rDNA sequencing and morphology of teliospores and basidia. Their genetic and phylogenetic analysis showed that strains of rust referred to as '*C. asterum*' on *Solidago* found in the US were not the same species as the original type specimen which was collected in Japan. As a consequence of this work, the *Coleosporium* species in the Americas infecting *Solidago* spp. and *Pinus* spp. were considered to be *C. solidaginis*, a species formerly synonymised with, but now distinct from *C. asterum sensu stricto* (Scheck, 2020a). McTaggart and Aime (2018) proposed the name *Coleosporium montanum* (Arthur &

F. Kern) McTaggart and Aime for the taxon that has commonly been identified as *C. asterum* in North America, being recognised as two genetically distinct species. Beenken et al. (2017) confirmed the distinction between *C. asterum* (infecting only *Aster* spp.) and *C. solidaginis* (infecting only *Solidago* spp.).

Some of the available literature on *C. asterum* and *C. solidaginis* may actually refer to *C. montanum*, as sequence differences between *C. montanum* accessions from *Symphyotrichum* spp. and *Solidago* spp. suggest that it may contain two host-specific cryptic species (McTaggart and Aime, 2018; Voglmayr et al., 2020).

The EPPO Global Database provides the following taxonomic identification for *C. asterum*:

Preferred name: *Coleosporium asterum* (Dietel) Sydow & P. Sydow.

Order: *Pucciniales*
Family: *Coleosporiaceae*
Genus: *Coleosporium*
Common name(s): Western pine-aster rust, needle cast of red pine, rust of *Solidago*, rust of aster.

Synonyms: *C. asterum* has the following synonyms (taking into account Index Fungorum (https://www.speciesfungorum.org/Names/SynSpecies.asp?RecordID=119921) and the Database of the Institute of Microbiology of the Chinese Academy of Sciences (https://nmdc.cn/fungalnames):
Stichopsora asterum Dietel.
Uredo solidaginis Schwein.
Coleosporium solidaginis (Schwein.) Thüm.
Peridermium montanum Arthur & F. Kern.
Coleosporium montanum (Arthur & F. Kern) McTaggart & Aime.

Coleosporium solidaginis f. *solidaginis*.
Coleosporium solidaginis f. *carpesii* (Sacc.) Sacc.

Since some of these synonyms are heterotypic (i.e. they are based on different type specimens), the decision as to whether they refer to the same taxon is subject to taxonomic debate. In some of the earlier literature, the name *Coleosporium asterum* was used for all three taxa. However, following Beenken et al. (2017) and McTaggart and Aime (2018), this pest categorisation considers *C. asterum, C. montanum* and *C. solidaginis* as distinct species.

The EPPO code[1] (Griessinger and Roy, 2015; EPPO, 2019) for *C. asterum* is COLSAS (EPPO, online). The EPPO Global Database, as of May 2023, considers *C. solidaginis* as synonym of *C. asterum*, while *C. montanum* is not reported in the page about *C. asterum*.

3.1.2. Biology of the pests

Coleosporium asterum, C. montanum and *C. solidaginis* are basidiomycete fungi of the order *Pucciniales,* family Coleosporiaceae causing rust diseases on *Pinus* spp. (aecial hosts) and on Asteraceae (telial hosts). *Coleosporium asterum* infects *Aster* spp. (aster), *C. montanum* infects *Symphyotrichum* spp. and *C. solidaginis* infects *Solidago* spp. (goldenrod). These fungi have a macrocyclic-heteroecious (heteromacrocyclic) life cycle, which includes five spore stages that develop on two unrelated groups of host plants (Figure 1).

The optimum temperature for germination of all spore types of most *Coleosporium* species, including *C. asterum and C. solidaginis,* is 20°C (Fergus, 1959). At such a temperature and in the presence of high humidity infection occurs within 24 h (Sinclair et al., 1989). The disease cycle begins on pine trees in late summer or early autumn, when needles of the aecial host are infected by wind-borne basidiospores produced on the telial host. The pathogens grow into and overwinters within the pine needles; however, symptoms of infection do not appear until the following spring.

Coleosporium asterum can also survive for over one year as mycelium within the needles of the pine host, where it can produce aecia for two to three consecutive summers (Sansford, 2015). Lowe (1972) reports that *C. asterum* may survive up to three years within the infected needles, even if conditions for spread are unfavourable (Sansford, 2015). Symptoms on the needles appear as yellow

[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).

spots, beneath which fruiting bodies (spermogonia) develop initially, followed by white, tongue-like fruiting bodies (aecia). When the aecia burst, wind-borne, bright orange aeciospores are released and reach the telial host during the summer. The aeciospores are no longer visible on pine hosts at the end of the summer, but tiny scars are left on yellow-brown spots/bands on needles. The aeciospores germinate in the presence of moisture on the leaves and stems of the telial host, leading to infection and to the appearance of orange pustules (uredinia).

In Asteraceae, the time between infection and the appearance of visible pustules is 10–15 days for *Coleosporium* spp. (Sinclair and Lyon, 2005). The uredinia produce urediniospores, which are long-lived and can cause multiple infection cycles on the telial host during the summer season, resulting in build-up of inoculum. Spread of urediniospores between herbaceous alternate hosts occurs by wind or by water-splash. In late summer, dark-coloured telia develop on the margins of the uredinial pustules. Studies on field infections of the Asteraceae host *Euthamia graminifolia* (syn. of *Solidago graminifolia*) by *C. asterum* found that most urediniospores fell within 1 m from infected source plants (Price et al., 2004). Basidiospores develop from the teliospores and are wind-blown from the alternate hosts: If they land upon a susceptible pine host, the needles may become infected, thereby completing the pathogen life cycle. *Coleosporium asterum*, along with other *Coleosporium* species, occasionally overwinters as urediniospores or uredinial mycelia in rosettes of leaves of its telial hosts (Kaneko, 1981).

The frequency of infection of *Pinus* hosts increases with their closer proximity to the telial hosts, as well as with the abundance of these hosts (Mihail et al., 2002).

Noteworthily, the urediniospores of *C. asterum* are capable of infecting other Asteraceae hosts, whereas the basidiospores only infect *Pinus* hosts. The teliospores could be killed by frost (Nicholls et al., 1965), and the basidiospores (which develop from the teliospores) were described by Lowe (1972) as '*small and delicate and cannot survive even a short period of temperature extremes or drought. Unless they land on susceptible pine needles shortly after dissemination and unless climate conditions are favourable, the basidiospores will perish*'. A few species of *Coleosporium* will survive for more than one year as mycelium in the living tissue of the pine host: *C. asterum* is one such rust species and may produce aecia on *Pinus* spp. for two to three subsequent summers (Lowe, 1972). Moreover, *C. asterum* can survive as telia as well as uredinial mycelium in overwintering herbaceous host plants, provided that climatic conditions remain favourable (i.e. humid and not frosty) (Lowe, 1972).

It has been proposed that insects may also have the potential to act as carriers of propagules of *Coleosporium* spp. Larvae of the mycophagous genus *Mycodiplosis* (Insecta, Diptera) are known to feed on rust spores and *C. asterum* was the most frequently sampled rust species in a survey carried out on 2,077 herbarium specimens collected in Maryland (Henk et al., 2011).

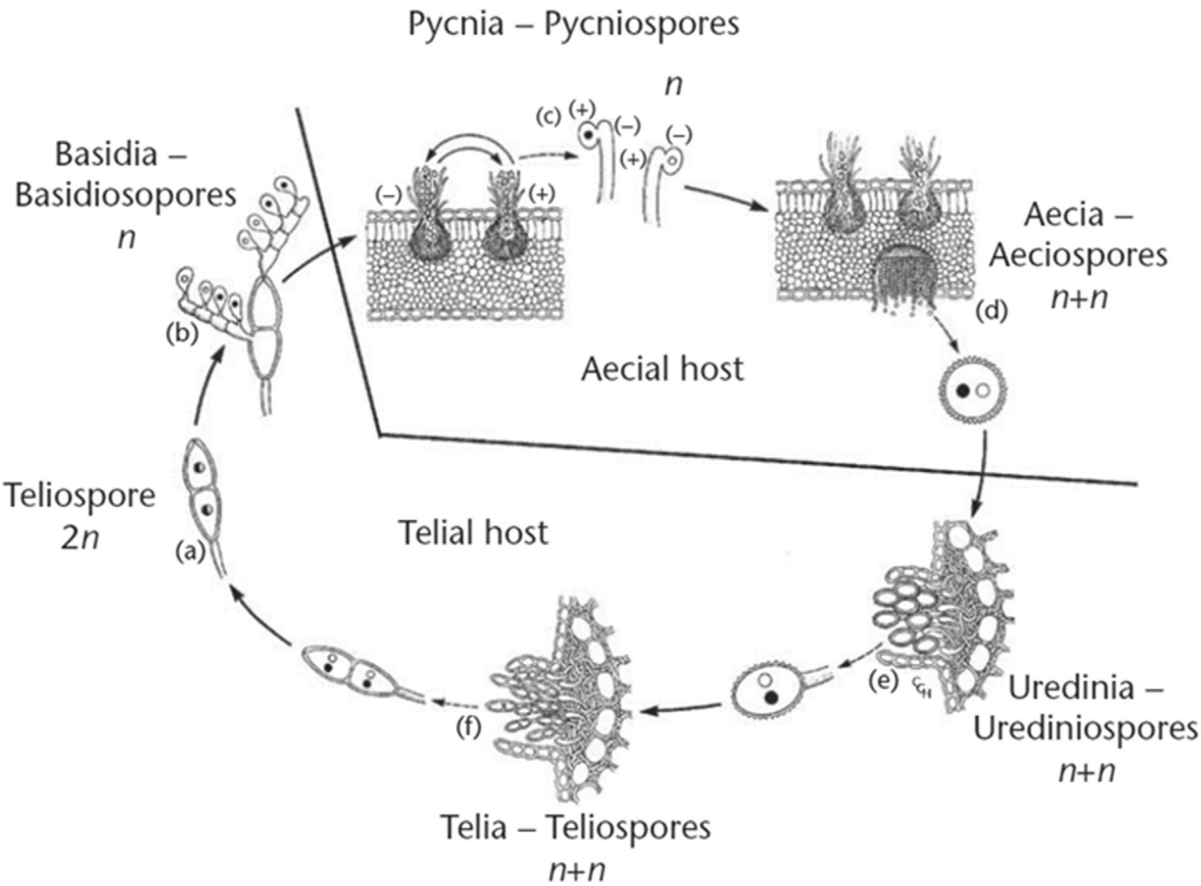

Figure 1: Life cycle of a macrocyclic-heteroecious rust. (a) mature, diploid teliospore; (b) basidia with basidiospores; (c) pycnial (spermogonial) stage; (d) aecial stage; (e) uredinial stage; and (f) telial stage. From Kolmer et al. (2009)

3.1.3. Host range/species affected

The host plant range of *C. asterum*/*C. montanum*/*C. solidaginis* has been subject to much debate and revision over many years. This was mainly due to the difficulties in determining whether these three taxa were taxonomic synonyms (see Section 3.1 – Identity and biology of the pest). Recent studies showed that they are not conspecific (Beenken et al., 2017; McTaggart and Aime, 2018). Additionally, molecular phylogenetic analyses indicate that new hosts may be colonised by *Coleosporium* spp. jumping to taxonomically related plants (within the same genus) (Beenken et al., 2017). Based on the same study, this particularly applies to the European *Coleosporium* species. Thus, the range of hosts that *C. asterum/C. montanum/C. solidaginis* can infect in nature might increase due to this process of host jumping. Scheck (2020a) points out that *C. solidaginis* has an unusually wide host range for a rust.

Coleosporium asterum, *C. montanum* and *C. solidaginis*, as the majority of Pucciniales, require two specific and unrelated plant hosts in order to complete their life cycle: the aecial host and the telial host (see Section 3.1.2). Although the actual host range of these three fungi remains uncertain, *Pinus* (Pinaceae family) has been reported to be the only known genus of aecial hosts. Lodgepole pine (*P. contorta*), jack pine (*P. banksiana*), red pine (*P. resinosa*) and Scots pine (*P. sylvestris*) are the main aecial hosts of *C. asterum* and *C. solidaginis*. Beyond *P. sylvestris*, two additional economically important and widespread *Pinus* species in the EU, namely *P. nigra* and *P. pinaster,* are reported to be hosts of *C. asterum* (CABI, 2021). Both lodgepole pine (*P. contorta*) and ponderosa pine (*P. ponderosa*) are the only known aecial hosts of *C. montanum* (Scheck, 2020b).

The telial stages under natural conditions are formed on numerous plant species from the family Asteraceae. Several species of aster (*Aster* spp.) are the main telial hosts reported for *C. asterum,* whereas the main telial host of *C. montanum* is *Symphyotrichum* spp.*,* and the main telial host of *C. solidaginis* is goldenrod (*Solidago* spp.), but the literature still lists *Aster* spp., *Solidago* spp. and *Symphyotrichum* spp. as telial hosts for each of the three *Coleosporium* species (Scheck 2020a,b).

A comprehensive list of the host plants reported so far for *C. asterum, C. montanum* and *C. solidaginis* is included in Appendix A (last updated: 20 March 2023).

3.1.4. Intraspecific diversity

It has been reported that results of host range testing can differ with the strain of *C. asterum* used (Anderson and Anderson, 1978), but these results might be due by conflating *C. asterum, C. montanum* and *C. solidaginis* in studies done before molecular tools became available. In any case, the ability of these fungi to differentiate sexual reproductive stages may enhance their genomic plasticity and adaptation to host preference and various adverse environmental conditions, including fungicide exposure.

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 for each of the three pathogens.

Symptomatology

Symptoms and signs on susceptible two- and three-needle *Pinus* spp. (aecial host) caused by *C. asterum*, *C. montanum* and *C. solidaginis* are very similar. These symptoms appear in the following spring, after the basidiospore infection in late summer/early autumn, as minute yellow spots on the infected needles. The honey-coloured spermogonia (also referred to as pycnia or pycnidia) occurring on these spots may be overlooked by the untrained observer (Lowe, 1972). Subsequently, pycnial droplets exude from these spots and then conspicuous white 'tongue-like' aecial blisters appear in May or June. By the end of the summer, the aecia disappear completely, leaving inconspicuous brown flecks on yellow-brown spots/bands on partly yellowed infected needles (Lowe, 1972). On young pine plants (less than 1 m in height), *C. asterum*, *C. montanum* and *C. solidaginis* cause severe defoliation of lower branches, and infections on seedlings may result in death of the lowest branch whorls (Baxter, 1931).

Detection by visual inspection is more difficult on its herbaceous telial hosts (asters and goldenrods): symptoms appear 10–15 days upon infection by aeciospores, but the presence of orange-yellow uredinia and orange-brown telia on the lower side of the leaves and on the stems is not sufficient to distinguish *Coleosporium* spp. occurring on these host species. Like other rust diseases, uredinia tend to coalesce and form typical rust symptoms consisting in browning of the tissues around fruiting bodies. Uredinia then rupture and expose the urediniospores in yellowish spore masses. Under rainy and humid conditions, the leaf surface can be fully covered by sporulating uredinia. Urediniospores on the lower leaf surface are accompanied by small yellowish to chlorotic lesions on the upper surface. No symptoms are observed on flowers and stems (Wang et al., 2017). Severe infections may result in leaf distortion, drying and premature senescence (Back et al., 2014). When the telial hosts are severely affected, symptoms of leaf blight may occur (Sinclair et al., 1989; Mihail et al., 2002). Yellow to dark-reddish telia can be observed on the abaxial side of the diseased leaves in late summer/early autumn. Because these symptoms and signs are similar to those caused by the three species and by other *Coleosporium* spp. affecting *Pinus* spp. or Asteraceae, detection based on symptomatology is not a reliable method.

Morphology

Microscopic examination makes it difficult to distinguish *C. asterum*, *C. montanum* and *C. solidaginis* from closely related *Coleosporium* spp. based on morphological traits. The morphological description of the uredinial and telial stages of a rust as observed by Back et al. (2014) on *Solidago virgaurea* var. *gigantea* includes yellow-orange and rounded uredinia (340–360 μm) on the surface of lower leaves; urediniospores are described as subglobose to ellipsoid, somewhat irregular and variable in shape, yellow-orange, verrucose (31.0–36.5 × 26.5–29.0 μm). Telia are described as orange-red and flat rounded, producing one-celled teliospores, obovoid, yellowish (73.0–86.5 × 22.0–37.0 μm). While this was considered to be *C. asterum* by these authors, it probably should be considered to be *C. solidaginis* following the classification of McTaggart and Aime.

The following morphological description of *P. montanum* (here considered as *C. montanum*) is provided by McTaggart and Aime (2018), based on the original description by Arthur and Kern (1914):

'Spermogonia hypophyllous, scattered, subcorticular, 0.3–0.5 × 0.5–1.0 mm, low-conical, 55–65 mm high. Aecia mostly epiphyllous, on yellowish spots, erumpent, flattened laterally, 1.0–1.5 × 0.528.30–0.8 mm; peridium colorless, delicate, cells 55–65 mm long, overlapping, walls 3–5 mm. Aeciospores oblong to linear oblong, 16–24 × 32–45 mm, wall colorless, 2–3 mm, closely and coarsely verrucose'.

The following morphological description of *C. asterum* is provided by Kaneko (1981): *'Spermogonia amphigenous', subepidermal, low-conical, 0.5–1 mm long by 0.3–0.5 mm broad, 90–140 μm high, orange-yellow becoming dark brown; spermatia obovoid or ellipsoid, 5.5–7.5 × 3–4.5 μm, hyaline. Aecia amphigenous, flattened laterally, 0.5–1.5 mm long by 0.5–1 mm high, orange-yellow; peridial cells ellipsoid, ovoid or polygonal, 30–65 × 22–36 μm, inner wall 2–5 μm thick, outer one 4–8 μm thick, verrucae of outer wall larger than those of inner one; aeciospores broadly ellipsoid to ellipsoid or polygonal, 20–30(36) × 18–24(26) μm, verrucose, with a smooth or reticulum-like spot, number of verrucae 25–40 per 100 μm^2, verrucae 0.5–2 μm broad, 0.5–2.5 μm high, wall 0.5–1 μm thick. Uredinia hypophyllous or caulicolous, scattered, rounded, 0.2–0.5 mm diam., soon naked, pulverulent, orange-yellow; urediniospores broadly ellipsoid to ellipsoid or polygonal, 20–32 × 14–24 μm, verrucose, with a smooth or reticulum-like spot, number of verrucae 25–45 per 100 μm^2, verrucae 0.8–2 μm broad, 0.5–3 μm high, wall 0.5 μm thick. Telia hypophyllous or caulicolous, scattered, rounded, 0.2–0.8 mm diam., orange-red; one-celled teliospores obovoid or ellipsoid, 45–90 × 19–30 μm excluding gelatinous apical layer, four-celled internal basidia 45–93 × 18–30 μm, catenulate, mature teliospores or basidia arranged in two layers, occasionally longitudinally septate, gelatinous apical layer 16–30 μm thick; basidiospores subglobose or globose, 16–24 × 14–21 μm'.*

Kaneko (1981) also compared the uredinial and telial states of '*C. asterum'* isolates from *Aster* and *Solidago* in North America with isolates from Japanese collections and found some differences in the morphological features of the urediniospores and of the basidiospores (Kaneko, 1981). However, as pointed out by McTaggart and Aime (2018), the morphology of spore stages cannot be considered as a reliable character for the identification of species of *Coleosporium* and the urediniospores of different species were often found to be similar in morphology.

DNA-based identification

Molecular phylogenetic studies have targeted the 28S region of rDNA to resolve relationships within and between genera of rust fungi, supporting *Coleosporium* as monophyletic (Maier et al., 2003). In a systematic analysis of *Coleosporium* species infecting *Solidago* and related hosts in North America, McTaggart and Aime (2018) suggested that when sequences in the 28S region cannot distinguish some species of *Coleosporium*, sequencing of the rDNA internal transcribed spacer 2 (ITS2) region may offer an alternative approach to separate closely related species, including *C. asterum, C. montanum* and *C. solidaginis*. In taxonomically challenging groups such as *Coleosporium*, a secondary locus was proposed to be sequenced when accurate identification and confirmation through morphology or host range is not feasible (McTaggart and Aime, 2018).

In GenBank (accessed on 22 April 2023), 32 accessions referred to *C. asterum*, 51 accessions referred to *C. solidaginis* and 18 accessions referred to *C. montanum* are currently available, including partial and complete sequences of the 5.8S, 18S, 28S rRNA, ITS2 and cytochrome c oxidase subunit 3 (COIII) gene regions. Given the changes in how these species were defined in the past, it is not always clear which taxa these accessions actually refer to. The distribution maps provided in Section 3.2.1 are based on molecular data from the recent publications where the naming has been changed. Species-specific primers are not available to amplify the pathogens directly from diseased host plant tissue or from fungal tissue.

No EPPO Standard is available for the detection and identification of *C. asterum, C. montanum* or *C. solidaginis*.

3.2. Pest distribution

3.2.1. Pest distribution outside the EU

Coleosporium asterum is reported from Asia (China, Japan, Korea) (Figure 2).

Coleosporium montanum is native to North America (Canada and USA) and has been introduced to Asia (South Korea) (McTaggart and Aime, 2018) (Figure 3).

Coleosporium solidaginis has been reported to be present in North America (Canada, USA), as well as in Asia (Japan) and Europe (Switzerland) (Farr and Rossman, 2023) (Figure 4).

These records are based on studies using molecular identification of the three species. The geographical distribution of *C. asterum, C. montanum* and *C. solidaginis* might be wider than that shown in Figures 2–4 as there are other reports from the literature on the occurrence of these fungi (Scheck 2020a,b), which were not considered here because they were not confirmed using molecular methods. Therefore, there is a key uncertainty about the geographical distribution of each of these species worldwide. A complete list of the countries and states/provinces from where these fungal species have been reported is included in Appendix B, including reports not based on molecular studies.

Figure 2: Global distribution of *Coleosporium asterum* (Source: literature; see Appendix D)

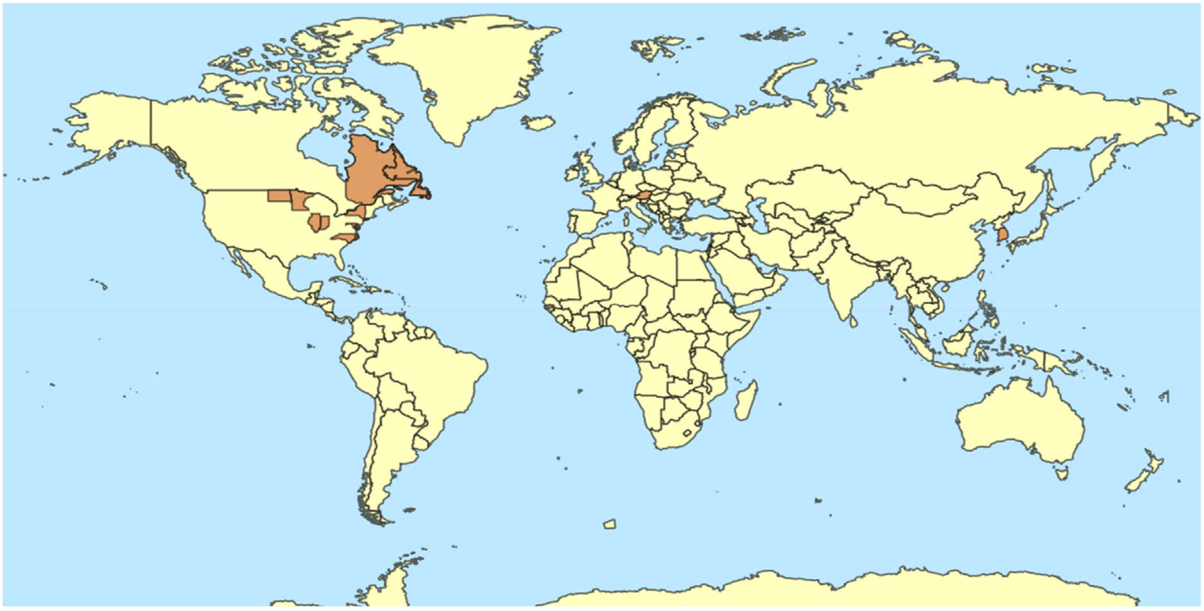

Figure 3: Global distribution of *Coleosporium montanum* (Source: literature; see Appendix E)

Figure 4: Global distribution of *Coleosporium solidaginis* (Source: literature; see Appendix F)

3.2.2. Pest distribution in the EU

> *Is the pest present in the EU territory? If present, is the pest in a limited part of the EU or is it scarce, irregular, isolated or present infrequently? If so, the pest is considered to be not widely distributed*.
>
> **Yes**, *Coleosporium asterum* has been reported in France and Portugal, *C. montanum* in Austria, and *C. solidaginis* in Germany. There is a key uncertainty about the presence and distribution in the EU, due to the until recently unresolved taxonomic separation of *C. asterum* from *C. solidaginis* and *C. montanum* and to their mostly unconfirmed occurrence.

There is a key uncertainty on the presence and distribution of *C. asterum, C. montanum* and *C. solidaginis* in the EU mainly due to the until recently unresolved taxonomic separation of these taxa. *Coleosporium asterum* is reported in France, Spain (unreliable record) and Portugal, *C. montanum* in Austria, and *C. solidaginis* in Germany.

Coleosporium asterum

In France, *C. asterum* has been detected in a molecular study of bio-aerosols at a green waste composting plant in Angers (Bru-Adan et al., 2009), but the finding was not subsequently confirmed.

Menéndez (2012) published in his Asturnatura blog photos of *C. asterum* on *Solidago virgaurea* taken in northern Spain (Asturias), in November 2007. However, the Spanish NPPO does not consider this as an official report and on 31 March 2023 confirmed that the plant health authorities of Asturias have carried out a specific survey in Monte Valsera to confirm or not the presence of *C. asterum* or *C. solidaginis*. They have collected samples of *Pinus pinaster*, with aecidia characteristic of this genus. No symptoms were found in *Solidago* spp. after visual observation, stereoscopic microscopy and molecular analysis. They confirmed the detection of *Coleosporium tussilaginis*, with a 100% similarity over 100% of the sequence with a strain isolated from *Sonchus* in California, and 99% similarity with two other strains isolated from other herbaceous plants. They have then contacted the person responsible for the publication in the Asturnatura blog who confirmed that his publication has no scientific validity as he has not carried out any molecular analysis. That reply confirms the current status in Spain for *Coleosporium asterum* as: absent, unreliable record.

There is one report of *C. asterum* in mainland Portugal on *Pinus pinaster* (Dos Santos and Sousa Da Cámara, 1954), but the publication is rather old. Four further records were then made in the Azores islands (https://registos.gbif.pt/occurrences/search?q=2513923#tab_recordsView), but this region is outside the remit of the pest categorisation (see Section 1.2). According to the Portuguese

NPPO, *C. asterum* has been detected in five locations in Portugal, but no official measures have been taken. Therefore, the status of the pest in Portugal is: 'Present: not widely distributed and not under official control' (information received on 8 March, 2023).

Coleosporium montanum

There are two records of *C. montanum* from Austria: The first one was in Lower Austria, in October 2017, on *Symphyotrichum lanceolatum* (voucher specimen WU 43136 deposited in the herbarium of the University of Vienna); the second one was in a garden in St. Willibald, Upper Austria, in October 2020, on *Symphyotrichum novae-angliae* (voucher specimen WU 43601) (Voglmayr et al., 2020).

Coleosporium solidaginis

The presence of *C. solidaginis* (as *C. asterum*) in Germany was reported five times (one dated November 2009 and four dated October 2011) on living plant material held in the herbarium of the Staatliches Museum für Naturkunde Karlsruhe (SMNK) (State Museum of Natural History) (Sansford, 2015). However, there is uncertainty about the identity of these isolates. Other records in Germany are reported as *C. solidaginis* on *Solidago gigantea* in the Upper Rhine Valley and in the botanical garden of the University of Constance (cited by Beenken et al., 2017). Despite the records, confirmation of the species of *Coleosporium* is still pending and according to the German NPPO (information received on 9 March, 2023), two possibilities are envisaged on the status of *C. asterum* in Germany: If *C. solidaginis* is considered as synonym to *C. asterum*, the pathogen is 'present, with no details'; whereas if *C. solidaginis* is not considered a synonym to *C. asterum*, the pathogen is 'absent (invalid record)'.

The current distribution of *C. asterum, C. montanum* and *C. solidaginis* in the EU is a key uncertainty, considering the taxonomical ambiguities and their unconfirmed occurrence, in most cases.

3.3. Regulatory status

3.3.1. Commission implementing regulation 2019/2072

Coleosporium asterum, C. montanum and *C. solidaginis* are not listed in Annex II of Commission Implementing Regulation (EU) 2019/2072, an implementing act of Regulation (EU) 2016/2031, or in any emergency plant health legislation. The pathogen *C. asterum* is mentioned in commodity risk assessments for bonsai *Pinus* spp. imported from Japan and China (EFSA PLH Panel, 2019, 2022).

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

A list of main hosts included in Annex VI of Commission Implementing Regulation (EU) 2019/2072 is provided in Table 2.

Table 2: List of plants, plant products and other objects that are hosts of *C. asterum, C. montanum and C. solidaginis* whose introduction into the Union from certain third countries is prohibited (Source: Commission Implementing Regulation (EU) 2019/2072, Annex VI)

List of plants, plant products and other objects whose introduction into the Union from certain third countries is prohibited			
	Description	**CN code**	**Third country, group of third countries or specific area of third country**
1.	Plants of [...] *Pinus* L., [...] 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 20 ex 0604 20 40	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, Türkiye and Ukraine

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, *Coleosporium asterum*, *C. montanum* and *C. solidaginis* are able to enter further into the EU via host plants for planting, other than seeds, and parts of host plants (e.g. cut flowers, foliage, branches), other than fruits.

There are four main pathways of further entry of *C. asterum, C. montanum* and *C. solidaginis* from infested third countries into the EU:

- Plants for planting of Asteraceae, other than seeds;
- Plants for planting of *Pinus* spp., other than seeds;
- Cut flowers of Asteraceae;
- Foliage and branches of *Pinus* spp.

Plants for planting of Asteraceae and *Pinus* host species: Infected Asteraceae and *Pinus* plants for planting other than seeds originating from third countries or areas where *C. asterum, C. montanum* and *C. solidaginis* have been reported may represent a pathway of further entry of these pathogens into the EU.

Cut flowers of Asteraceae: *C. asterum* has been reported to be repeatedly intercepted in the UK on cut flowers of *Solidago* sp. imported from Kenya, Zambia and Zimbabwe (Sansford, 2015). If *C. asterum* is restricted to *Aster*, whereas if *Solidago* is only infected by *C. solidaginis*, then it is likely that the interceptions are of *C. solidaginis* rather than *C. asterum*. No records of the three pathogens dealt in this pest categorisation are available in these countries, but it is suspected that *Coleosporium* spp. may occur in Africa. Moreover, these pathogens have been reported in other countries that export cut flowers of the host genera to the EU. Since uredinial pustules on Asteraceae hosts develop 10–15 days after infection, exclusion may be possible only provided that the pathogens have developed obvious pustules by the time an infected shipment arrives at the port of entry (Sansford, 2015). However, it is likely that the pathogens can enter as latent infections. Alternatively, symptomatic flowers that are disposed on a compost heap could potentially represent an inoculum source to susceptible ornamentals or pine species growing nearby. This also applies to other potential host plant parts, in case of disposal as compost. Sansford (2015) points out that cut flowers have a limited lifespan and, although rusts need a living host to complete their life cycle, once infected flowers are disposed, the pathogen could in theory overwinter on infected tissue of Asteraceae or infect hosts growing nearby in the same season. The detection of *C. asterum* DNA in bioaerosols emanating from a green waste composting site in France supports this possibility, although the viability of the inoculum was not tested (Bru-Adan et al., 2009).

Foliage and branches of *Pinus* spp.: Foliage of *Pinus* spp. is permitted to be imported into the EU from non-EU European countries if accompanied by a phytosanitary certificate. Further entry of *C. asterum, C. montanum* and *C. solidaginis* through this pathway is unlikely because of the phytosanitary certificate requirement, but entry is possible since there can be asymptomatic infection.

Given the limited dispersal distance of *Coleosporium* spp. infection via wind-borne spores (see Section 3.1.2), it is unlikely for these pathogens to further enter the EU by natural means (wind, water-splash, insects, etc.) because of the long distance between the infested third countries and the EU Member States. However, one infested third country (Switzerland) is neighbouring EU MSs; therefore, this possibility cannot be excluded. Moreover, long-distance spread of rust fungi has been frequently observed (see Section 3.4.3).

Seed transmission has not been reported for *Coleosporium* spp.

Soil and water are not known to be pathways of entry for *C. asterum, C. montanum* and *C. solidaginis* but soil and growing media (including pine bark) containing infected plant debris could represent a pathway of entry.

A list of all the potential pathways for the entry of these three pathogens into the EU is included in Table 3.

Table 3: Potential pathways for *Coleosporium asterum, C. montanum* and *C. solidaginis* into the EU

Pathways (e.g. host/ intended use/source)	Life stage	Relevant mitigations [e.g. prohibitions (Annex VI), special requirements (Annex VII) or phytosanitary certificates (Annex XI) within Implementing Regulation 2019/2072]
Host plants for planting, other than seeds	Mycelium, basidiospores, aeciospores, urediniospores, teliospores	Annex VI (1) bans the introduction of plants of planting of *Pinus* L. other than fruit and seed from certain third countries (including countries where the pest occurs: China, Republic of Korea, Japan, Russia, USA, etc.), with some exceptions (e.g. imports of bonsai *Pinus* from Korea and Japan, that are permitted under the terms of derogations). There are currently no phytosanitary requirements for plants for planting of Asteraceae entering the EU. There is a derogation for artificially dwarfed pines from Japan (Regulation 2020/1217); Annex VII (10 and 11) requires official statement of special requirements for the introduction into the Union from certain third countries of trees and shrubs, intended for planting, other than seeds and plants in tissue culture. These requirements are not specifically targeted against *C. asterum, C. montanum* or *C. solidaginis*.
Parts of host plants (e.g. cut flowers, foliage, branches) other than fruits	Mycelium, basidiospores, aeciospores, urediniospores, teliospores	Annex XI (A.3) requires a phytosanitary certificate for foliage, branches and other parts of conifer (Pinales) plants, without flowers or flower buds, being goods of a kind suitable for bouquets or for ornamental purposes, fresh, from third countries other than Switzerland. Annex XI (A.3) also requires a phytosanitary certificate for parts of plants, other than fruits and seeds including *Solidago* spp. from third countries, other than Switzerland. These requirements are not specifically targeted for *C. asterum. C. montanum* or *C. solidaginis* Annex XI (A.6) requires a phytosanitary certificate for cut flowers including *Aster* spp. from certain third countries.

Notifications of interceptions of harmful organisms began to be compiled in Europhyt in May 1994 and in TRACES in May 2020. As of 31 March 2023, there were two records of interception of *C. asterum* in the Europhyt and TRACES databases, both reported by the UK in 2016 on *Solidago* spp. from Kenya. Since detections on *Solidago* spp. are now credited to *C. solidaginis* (Scheck, 2020a), these UK interceptions are likely to have been of *C. solidaginis* rather than *C. asterum*.

However, since *C. asterum, C. montanum* and *C. solidaginis* are not quarantine pests, the EU Member States have no obligation to notify interceptions of the pathogens via Europhyt/TRACES.

California has intercepted *C. solidaginis* on multiple *Solidago* spp. florist stock shipments from Colombia, Ecuador and the Dominican Republic, as well as on wreaths with *Pinus* spp. from Washington State (US) (Scheck, 2020a).

The quantity of imports of commodities of hosts imported into the EU from countries where *C. asterum, C. montanum* or *C. solidaginis* are reported is provided in Table 4.

Table 4: EU annual imports of commodities of main hosts from countries where *Coleosporium asterum, C. montanum* or *C. solidaginis* are reported, 2016–2020 (in 100 kg) Source: Eurostat accessed on 2 January 2021

Potential commodity pathway	HS code	2016	2017	2018	2019	2020
Live forest trees	0602 90 41	133.06	135.68	0.45	0.05	0.63

Potential commodity pathway	HS code	2016	2017	2018	2019	2020
Fresh conifer branches, suitable for bouquets or ornamental purposes	0604 20 40	0	555.07	707.19	722.12	227.81
Fresh cut flowers and buds, of a kind suitable for bouquets or for ornamental purposes*	0603 19 70	240,122.04	39,536.26	278,194.84	308,834.79	284,143.98

*: (Excl. roses, carnations, orchids, gladioli, ranunculi, chrysanthemums and lilies).

3.4.2. Establishment

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

Yes. *Coleosporium asterum, C. montanum* and *C. solidaginis* could potentially become established in the risk assessment area.

Coleosporium asterum, C. montanum and *C. solidaginis* are likely to further establish both outdoors and under protected plant growth conditions in the EU. The area endangered by these three pathogens includes areas where host plants in the Asteraceae and Pinaceae families co-exist. These hosts are widely distributed in the EU.

Given their biology, *C. asterum, C. montanum* and *C. solidaginis* could potentially be transferred from the pathways of entry (host plants for planting and host plant parts) to the host plants, particularly *Pinus* spp. and wild or ornamental Asteraceae grown in the EU, *via* the airborne aeciospores, basidiospores or urediniospores. The probability of such transfer depends on the volume and frequency of imported commodities, their destination (e.g. nurseries, retailers), the distance between the aecial or telial hosts growing in managed or unmanaged (natural) environments in the EU and the spread potential of the spores of these rust fungi, as well as on the management of plant residues. Climate mapping is the main method for identifying areas that could provide suitable conditions for the establishment of a pest taking key abiotic factors into account (Baker, 2002). Availability of hosts is considered in Section 3.4.2.1. Climatic factors are considered in Section 3.4.2.2.

3.4.2.1. EU distribution of main host plants

Solidago spp. and *Aster* spp. are commonly grown as ornamental plants and various members of the family Asteraceae are also often found as weeds. *Symphyotrichum* is a genus that has been split off from the genus *Aster*. The majority of species in the genus *Symphyotrichum* are native to North America. Few species of this genus have been introduced to Europe as garden specimens, becoming naturalised (GBIF, 2023), but these are a small minority compared to the native North American species. In the areas where susceptible species of two- or three-needle pines (aecial hosts) co-exist with susceptible telial hosts of the family Asteraceae, *C. asterum, C. montanum* and *C. solidaginis* have the potential to establish by completing their lifecycle.

An overview on the probability of the presence of the genus *Pinus* in Europe is provided in Figure 5.

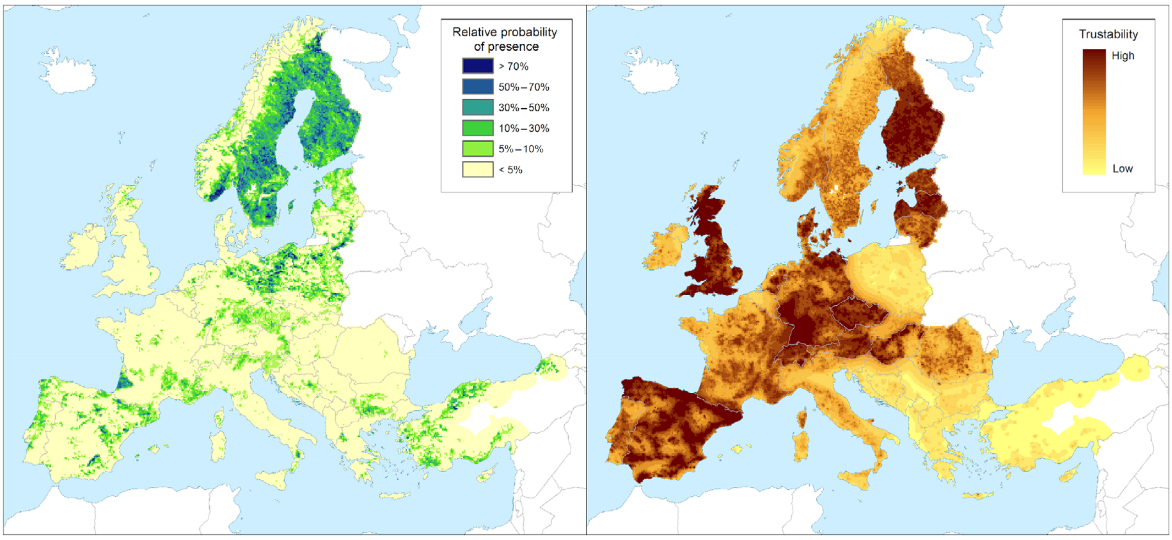

Figure 5: Left panel: Relative probability of presence (RPP) of the genus *Pinus* in Europe, mapped at 100 km^2 resolution. The underlying data are from European-wide forest monitoring data sets and from national forestry inventories based on standard observation plots measuring in the order of hundreds m^2. RPP represents the probability of finding at least one individual of the taxon in a standard plot placed randomly within the grid cell. For details, see Appendix (courtesy of JRC). Right panel: Trustability of RPP. This metric expresses the strength of the underlying information in each grid cell and varies according to the spatial variability in forestry inventories. The colour scale of the trustability map is obtained by plotting the cumulative probabilities (0–1) of the underlying index (for details, see Appendix C)

3.4.2.2. Climatic conditions affecting establishment

Climatic types in the EU do not differ from those prevailing in areas of North America where *C. asterum, C. montanum* and *C. solidaginis* are widely distributed (Cfa, Cfb, Dfb, Dfc) (Figures 6–8). *C. asterum* and *C. solidaginis* are also likely to establish under climate type Cfc (Figures 6 and 8). Southern regions in southern EU MSs (e.g. most of the Iberian Peninsula) appear unsuitable to establishment due to climatic conditions, but most central, northern and eastern Europe is suitable.

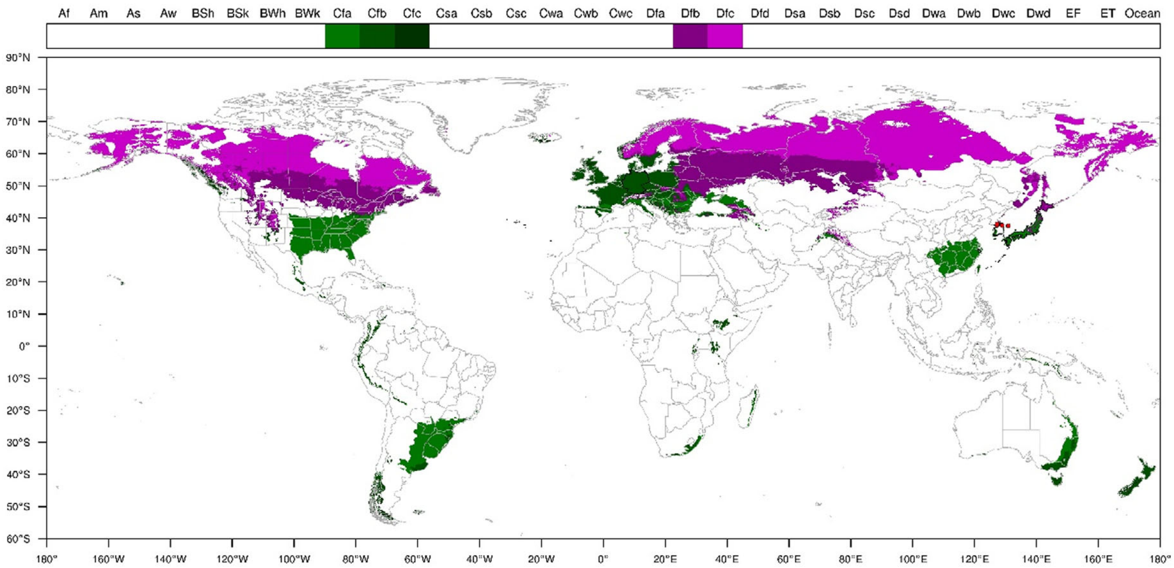

Figure 6: Distribution of Köppen–Geiger climate types Cfa, Cfb, Cfc, Dfb and Dfc that occur in the EU and in third countries where *Coleosporium asterum* has been reported. The legend shows the list of Köppen–Geiger climates

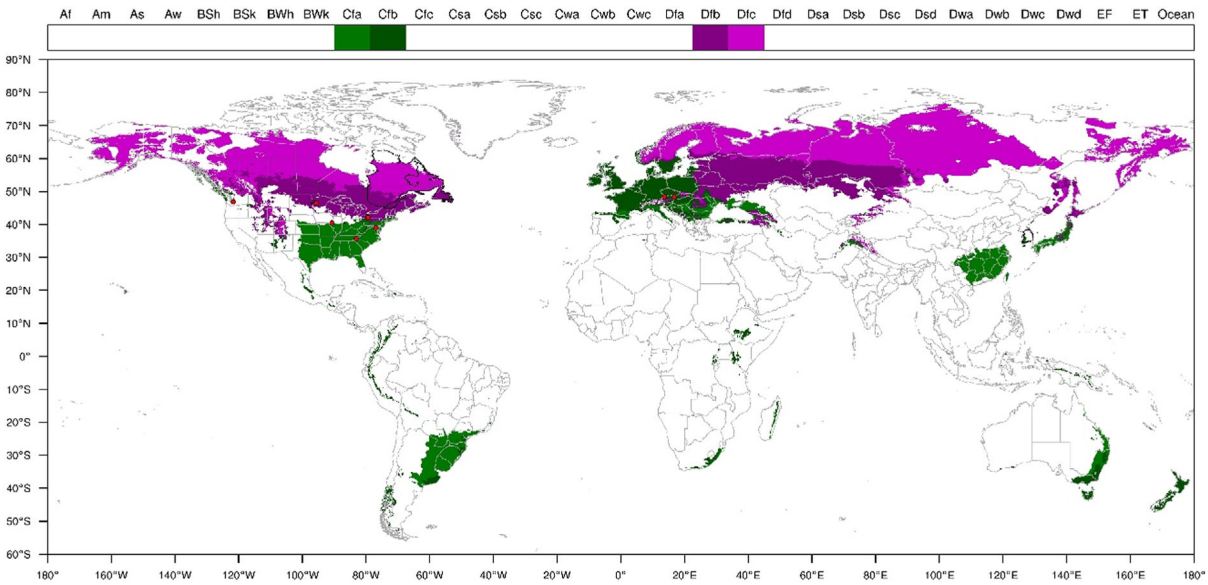

Figure 7: Distribution of Köppen–Geiger climate types Cfa, Cfb, Dfb and Dfc that occur in the EU and in third countries where *Coleosporium montanum* has been reported**.** The legend shows the list of Köppen–Geiger climates

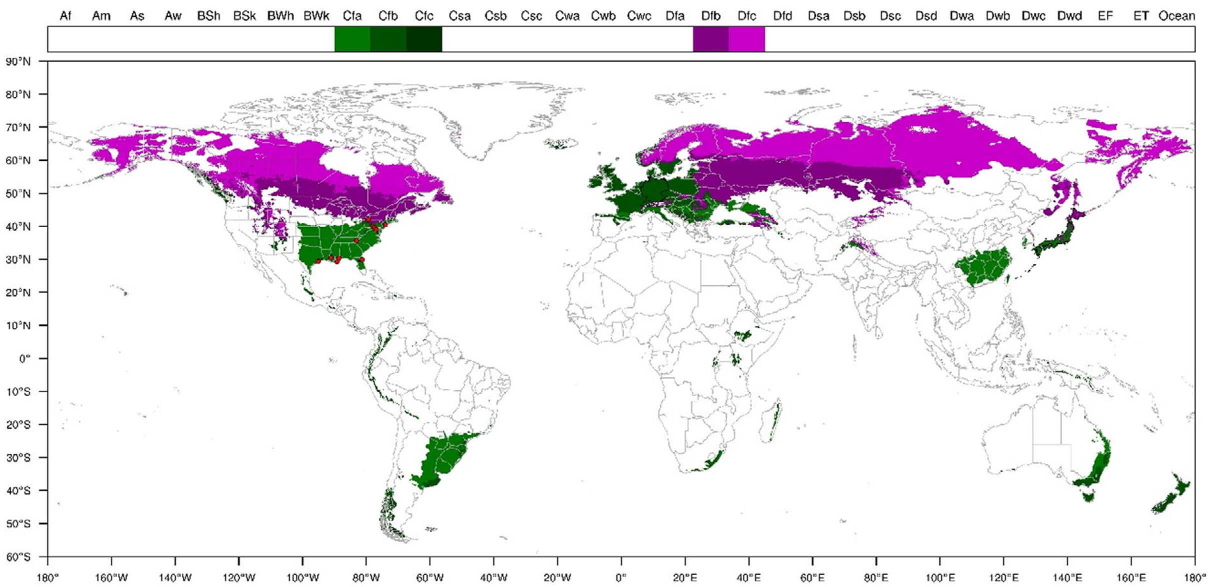

Figure 8: Distribution of Köppen–Geiger climate types Cfa, Cfb, Cfc, Dfb and Dfc that occur in the EU and in third countries where *Coleosporium solidaginis* has been reported. The legend shows the list of Köppen–Geiger climates

3.4.3. Spread

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

Coleosporium asterum, C. montanum and *C. solidaginis* could potentially spread within the EU by both natural and human-assisted means.

Comment on plants for planting as a mechanism of spread.

Host plants for planting is a main means of spread of these pathogens within the EU.

Spread by natural means. Wind-borne aeciospores of the three pathogens produced on susceptible *Pinus* spp. infect *Aster* spp., *Solidago* spp. and/or *Symphyotrichum* spp. during the summer. Urediniospores produced on Asteraceae may spread by wind or by water splash and give rise to repeated infection cycles. In late summer/early autumn, basidiospores are produced on the telial host and may infect pine needles, thereby completing the life cycle. The distance of disease spread caused by *C. asterum* basidiospores was estimated to be up to 140 m (Mihail et al., 2002), whereas Nicholls and Anderson (1976) recommended keeping a telial host-free buffer zone ~ 305 m wide around young pine plantations as protection from *Coleosporium* rust infection. A wider buffer zone of up to 800 m from the edge of the outbreak was recommended by the Canadian Food Inspection Agency (Sansford, 2015). There is uncertainty about such a distance, as rust fungal spores can travel long distances in air currents (Kakishima et al., 2017; Prank et al., 2019; Casamayor et al., 2023).

It has been proposed that insects may also have the potential to act as carriers of propagules of *Coleosporium* spp. The role of mycophagous Diptera in the ecology of *C. asterum, C. montanum* and *C. solidaginis* has not been demonstrated experimentally, but the adult stages have the potential to disperse spores of these rust fungi (see Section 3.1.2).

Spread by human-assisted means. The three pathogens could potentially spread over long distance via the movement of infected host plants for planting (*Pinus* spp., *Aster* spp., *Solidago* spp. or *Symphyotrichum* spp.), other than seeds and host plant parts (e.g. cut flowers, foliage, branches), other than fruits.

3.5. Impacts

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

Yes, the further introduction and spread of *Coleosporium asterum*, *C. montanum* and *C. solidaginis* is likely to have an economic and environmental impact in the EU, despite the uncertainty on their host range.

The host range of *C. asterum, C. montanum* and *C. solidaginis* as reported in the literature is uncertain due to the difficulties in identifying these rusts to species level (see Section 3.1.1). The environmentally and/or economically relevant hosts of *C. asterum, C. montanum* and *C. solidaginis* include *Pinus* species (e.g. those grown for timber production, ornamentals or Christmas trees) as well as ornamental plants in the Asteraceae family. Moreover, some members of Asteraceae became invasive weeds in several areas of the EU where they had been previously introduced as ornamentals (Lambdon et al., 2008), thereby increasing the potential of these pathogens to complete their life cycle (Sansford, 2015).

Coleosporium asterum, C. montanum and *C. solidaginis* are likely to have little impact on *Pinus* spp. in mature timber plantations, since only young trees suffer significant damage in the areas of the pathogen's current distribution. Impact on nursery pine trees (e.g. those intended for afforestation, ornamentals and Christmas trees) may be relevant if eradication measures against susceptible weed telial hosts (Asteraceae) are not taken. Also, young pine trees in native forests are prone to infection, and therefore, regeneration processes may be affected (Sansford, 2015).

Asteraceae (e.g. *Aster*, *Solidago, Symphyotrichum*) grown for ornamental purposes (e.g. cut flower industry, nurseries, gardens) are likely to suffer the largest impact if these pathogens will be further introduced in the EU and in the absence of adequate control measures. Indeed, repeating cycles of secondary infection have been reported to cause defoliation of *Aster, Solidago* and *Symphyotrichum* plants, reducing the production of flowers (Scheck, 2020b).

3.6. Available measures and their limitations

Are there measures available to prevent pest entry, establishment, spread or impacts such that the risk becomes mitigated?

Yes. Although not always specifically targeted against *Coleosporium asterum, C. montanum* or *C. solidaginis*, existing phytosanitary measures (see Sections 3.3.1 and 3.4.1) mitigate the likelihood of the further entry of these pathogens on certain host plants and plant products into the EU. Potential additional measures are also available to further mitigate the risk of further entry, establishment and spread of the three pathogens in the EU (see section 3.6.1).

3.6.1. Identification of potential additional measures

Phytosanitary measures (prohibitions) are currently applied to some host plants for planting (see Section 3.3.1).

Additional potential risk reduction options and supporting measures are shown in Sections 3.6.1.1 and 3.6.1.2.

3.6.1.1. Additional potential risk reduction options

Potential additional control measures are listed in Table 5.

Table 5: Selected control measures (a full list is available in EFSA PLH Panel, 2018) for pest entry/establishment/spread/impact in relation to currently unregulated hosts and pathways. Control measures are measures that have a direct effect on pest abundance

Control measure/ Risk reduction option (Blue underline = Zenodo doc, Blue = WIP)	**RRO summary**	**Risk element targeted (entry/ establishment/ spread/impact)**
Require pest freedom	Plant or plant products should come from a country officially free from the pest, or from a pest-free area or from a pest-free place of production.	Entry/Spread
Growing plants in isolation	Description of possible exclusion conditions that could be implemented to isolate the crop from pests and if applicable relevant vectors. E.g. a dedicated structure such as glass or plastic greenhouses. Aecial (*Pinus* spp.) and telial (*Aster* spp., *Solidago* spp. and *Symphyotrichum* spp.) susceptible host plant species should not be present/grown in the same area to avoid completion of the life cycle of the pathogens.	Entry (reduce contamination/ infestation)/ establishment/ spread
Managed growing conditions	Proper field drainage, plant distancing, use of pathogen-free agricultural tools (e.g. pruning tools), and removal of infected plants and plant debris in the field could potentially mitigate the likelihood of infection at origin as well as the spread of the pathogen.	Entry (reduce contamination/ infestation)/spread/ impact
Crop rotation, associations and density, weed/ volunteer control	Crop rotation, associations and density, weed/volunteer control are used to prevent problems related to pests and are usually applied in various combinations to make the habitat less favourable for pests. The measures deal with (1) allocation of crops to field (over time and space) (multicrop, diversity cropping) and (2) to control weeds and volunteers as hosts of pests/vectors. Considering the possible role of Asteraceae weeds in the life cycle of the pathogen, weed control may represent an efficient control measure	Entry/establishment/ impact
Use of resistant and tolerant plant species/ varieties	Resistant plants are used to restrict the growth and development of a specified pest and/or the damage they cause when compared to susceptible plant varieties under similar environmental conditions and pest pressure. It is important to distinguish resistant from tolerant species/ varieties. *Coleosporium asterum/montanum/solidaginis*-resistant *Pinus* spp. offer a sustainable alternative to susceptible hosts used for timber production, afforestation, ornamentals or Christmas trees	Entry/establishment/ impact

Control measure/ Risk reduction option (Blue underline = Zenodo doc, Blue = WIP)	RRO summary	Risk element targeted (entry/ establishment/ spread/impact)
Roguing and pruning	Roguing is defined as the removal of infested plants and/or uninfested host plants in a delimited area, whereas pruning is defined as the removal of infested plant parts only without affecting the viability of the plant. The pathogens may be removed from host plants through pruning activity: removal of new symptomatic shoots should take place in May on *Pinus* spp.	Spread/impact
Chemical treatments on crops including reproductive material	Fungicide treatment (e.g. copper derivatives, carbamates, pyridinecarboxamides (e.g. boscalid) + pyrazoles (e.g. pyraclostrobin), triazoles (e.g. myclobutanil) of the aecial and telial hosts are reported to be effective against rust fungi.	Establishment/ spread/impact
Chemical treatments on consignments or during processing	Use of chemical compounds that may be applied to plants or to plant products after harvest, during process or packaging operations and storage. The treatments addressed in this information sheet are: a) fumigation; b) spraying/dipping pesticides; c) surface disinfectants; d) process additives; e) protective compounds Fungicide treatments are effective against rust fungi on *Pinus* spp. (EFSA PLH Panel, 2019, 2022).	Entry/spread
Limits on soil	Soil and growing media containing infected plant debris could represent a pathway of further entry and of spread for the pathogen. Therefore, plants, plant products and other objects (e.g. used farm machinery) should be free from soil to ensure freedom from the pathogen.	Entry/spread
Waste management	*Coleosporium asterum* (possibly *C. solidaginis*? See Section 3.4.1) has been intercepted on cut flowers of Asteraceae spp. imported from Africa. Infected cut flowers and waste of *Pinus* spp. plants grown in nurseries, gardens, etc. may be discarded on compost heaps (private and public, including local authority windrows recycling green waste) and where host species are located nearby this could result in transfer of spores from infected green waste to living plants. Proper waste management (e.g. incineration) should reduce the risk of pathogen dispersal.	Establishment/ spread
Post-entry quarantine and other restrictions of movement in the importing country	*Coleosporium asterum* can survive as mycelium in the living tissue (needles) of *Pinus* spp. for 2–3 subsequent summers (Lowe, 1972). Therefore, imported host plants should stay for a minimum of 3 months and up to 36 months in a post-entry quarantine station in the EU and are inspected at least twice during that period. Plants with symptoms are tested molecularly for the presence of the pathogens.	Establishment/ spread

3.6.1.2. Additional supporting measures

Potential additional supporting measures are listed in Table 6.

Table 6: Selected supporting measures (a full list is available in EFSA PLH Panel, 2018) in relation to currently unregulated hosts and pathways. Supporting measures are organisational measures or procedures supporting the choice of appropriate risk reduction options that do not directly affect pest abundance

Supporting measure (Blue underline = Zenodo doc, Blue = WIP)	Summary	Risk element targeted (entry/establishment/spread/impact)
Inspection and trapping	All plants destined for export are inspected in the production country several times per year (from April to September over a 3-year period) for the presence of rust symptoms or *C. asterum/ C. montanum/ C. solidaginis* host-specific signs (spermogonia and aecia on *Pinus* spp.; uredia and telia on Asteraceae spp. hosts). Plants showing symptoms and signs are removed or tested for the presence of the pathogen. This measure also applies to host commodities traded/moved within the EU.	Entry/establishment/spread
Laboratory testing	DNA-based identification of *C. asterum, C. montanum* and *C. solidaginis* (e.g. multilocus gene sequencing) is applied to determine if the pathogens are present.	Entry/spread
Sampling	Necessary as part of other RROs.	Entry/spread
Phytosanitary certificate and plant passport	Recommended for host plants, including plant parts (e.g. cut flowers, foliage and branches).	Entry/spread
Certified and approved premises	If plant material originates from an approved premise, e.g. from a pest-free area, the likelihood of commodity being infected is assumed to be reduced.	Entry/spread
Certification of reproductive material (voluntary/official)	Host plants come from within an approved propagation scheme and are certified pest free (level of infestation) following testing. Used to mitigate against pests that are included in a certification scheme.	Entry/spread
Delimitation of Buffer zones	Delimitation of a buffer zone is an effective measure to prevent further spread of the pathogens from the outbreak area and to maintain a pest-free production place (PFPP), site (PFPS) or area (PFA). For the delimitation of the buffer zone, the minimum distance (at least 300 m) between the aecial and telial hosts should be also taken into consideration. Sansford (2015) recommends extending the buffer zone to 800 m, but there is uncertainty about this distance.	Spread
Surveillance	Surveillance is an effective measure to define pest-free areas or pest-free places of production as well as to prevent further spread of the pathogen.	Spread

3.6.1.3. Biological or technical factors limiting the effectiveness of measures

- Long incubation period (up to 36 months) before symptoms appear on the aecial host (*Pinus* spp.);
- Asymptomatic plants might remain undetected;
- The similarity of symptoms and signs caused by *C. asterum, C. montanum* and *C. solidaginis* with those of other *Coleosporium s*pecies affecting *Pinus* spp. hampers the detection of the pathogens based on symptomatology and fruiting structures;
- PCR-specific protocols for the detection and identification of *Coleosporium asterum, C. montanum* and *C. solidaginis* are unavailable.

3.7. Uncertainty

- A key uncertainty exists on the geographical distribution of the three pathogens in the EU and worldwide, due to the synonymy accepted until recently between *C. asterum, C. montanum* and *C. solidaginis,* and the lack of molecular studies.

4. Conclusions

Coleosporium asterum, C. montanum and *C. solidaginis* have been reported from some EU MSs, but with a restricted distribution. Therefore, *C. asterum, C. montanum* and *C. solidaginis* satisfy the criteria that are within the remit of EFSA to assess for these species to be regarded as potential Union quarantine pest (Table 7).

Table 7: The Panel's conclusions for *Coleosporium asterum, Coleosporium montanum* and *Coleosporium solidaginis* 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)	Yes, the identity of the pests is clearly defined and the pathogens have been shown to produce consistent symptoms and to be transmissible.	None
Absence/presence of the pest in the EU (Section 3.2)	Yes, *C. asterum* is reported from some EU MS (France and Portugal), but with a limited distribution. *Coleosporium montanum* is reported from Austria, with a limited distribution. *Coleosporium solidaginis* is reported from Germany, with a limited distribution.	Uncertainty on the distribution of *C. asterum, C. montanum* and *C. solidaginis* in the EU due to the synonymy accepted until recently between the three fungi, and the lack of molecular studies.
Pest potential for entry, establishment and spread in the EU (Section 3.4)	Yes, the pathogens are able to further enter into, become established and spread within the EU territory through the following pathways: host plants for planting other than seeds and host plant parts other than fruits. Spread may occur by both natural and human-assisted means	None.
Potential for consequences in the EU (Section 3.5)	Yes, the pest's further introduction and spread is likely to have an economic and environmental impact on the EU territory	None.
Available measures (Section 3.6)	Yes, although not always specifically targeted against *C. asterum, C. montanum* or *C. solidaginis*, phytosanitary measures are available to mitigate the likelihood of the pathogen's further entry on certain host plants and plant products into the EU territory.	None.
Conclusion (Section 4)	*Coleosporium asterum, Coleosporium montanum* and *Coleosporium solidaginis* satisfy the criteria assessed by EFSA for consideration as a Union quarantine pest.	Uncertainty on the distribution of *C. asterum, C. montanum* and *C. solidaginis* in the EU due to the synonymy accepted until recently between the three fungi, and the lack of molecular studies
Aspects of assessment to focus on/scenarios to address in future if appropriate:	The main knowledge gap concerns the distribution of the pathogens in the EU and worldwide, due to the until recently accepted synonymy between *C. asterum, C. montanum* and *C. solidaginis* and the lack of molecular studies. The development of specific PCR-protocols would allow direct identification of each of the three pathogens on infected host plants upon import/trade.	

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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, 2022)
Control (of a pest)	Suppression containment or eradication of a pest population (FAO, 2022)
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, 2022)
Eradication (of a pest)	Application of phytosanitary measures to eliminate a pest from an area (FAO, 2022)
Establishment (of a pest)	Perpetuation for the foreseeable future, of a pest within an area after entry (FAO, 2022)
Greenhouse	A walk-in static, closed place of crop production with a usually translucent outer shell, which allows controlled exchange of material and energy with the surroundings and prevents release of plant protection products (PPPs) into the environment.
Hitchhiker	An organism sheltering or transported accidentally via inanimate pathways including with machinery, shipping containers and vehicles; such organisms are also known as contaminating pests or stowaways (Toy and Newfield, 2010).
Impact (of a pest)	The impact of the pest on the crop output and quality and on the environment in the occupied spatial units
Introduction (of a pest)	The entry of a pest resulting in its establishment (FAO, 2022)
Pathway	Any means that allows the entry or spread of a pest (FAO, 2022)
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, 2022)
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, 2022)
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, 2022)

Appendix A – *Coleosporium asterum* host plants/species affected

Host status	Host name	Plant family	Common name	Reference
Cultivated hosts	*Aster*	Asteraceae	–	Nicholls and Anderson (1976)
	Aster ageratoides	Asteraceae	–	Sjamsuridzal et al. (1999)
	Aster formosana	Asteraceae	–	Berndt (1996)
	Aster pilosus	Asteraceae	–	Park et al. (2012)
	Aster glehnii	Asteraceae	–	Suzuki et al. (2018)
	Aster microcephalus var. avatus	Asteraceae	–	Suzuki et al. (2018)
	Aster iinumae	Asteraceae	–	Suzuki et al. (2018)
	Aster macrophyllus	Asteraceae	–	Mihail et al. (2002)
	Aster glehnii var. hondoensis	Asteraceae	–	Hosoe et al. (2007)
	Erigeron strigosus	Asteraceae	Daisy fleabane Rough fleabane	Lee et al. (2018)
	Euthamia graminifolia	Asteraceae	–	Price et al. (2004)
	Kalimeris indica	Asteraceae	–	Zhuang and Wang (2006)
	Launaea pinnatifida	Asteraceae	–	Sinha and Singh (2012)
	Solidago	Asteraceae	Goldenrod	Nicholls and Anderson (1976)
	Solidago altissima	Asteraceae	–	Nicholls et al. (1968)
	Solidago azorica	Asteraceae	–	Talhinhas et al. (2019)
	Solidago canadensis	Asteraceae	Canadian goldenrod	Wang et al. (2017)
	Solidago gigantea	Asteraceae	–	Kruse et al. (2017)
	Solidago odora	Asteraceae	–	Tucker et al. (1999)
	Solidago sempervirens	Asteraceae	–	Talhinhas et al. (2019)
	Solidago virgaurea	Asteraceae	–	Kruse et al. (2017)
	Solidago virgaurea var. gigantea	Asteraceae	Goldenrod	Back et al. (2014)
	Pinus spp.	Pinaceae	–	Marinova-Todorova et al. (2020)
	Pinus banksiana	Pinaceae	Jack pine	Nicholls and Anderson (1976)
	Pinus densiflora		Japanese umbrella pine	Suzuki et al. (2018)
	Pinus resinosa	Pinaceae	Red pine	Nicholls et al. (1968)
	Pinus sylvestris	Pinaceae	Scots pine	Suzuki et al. (2018)

Appendix B – *Coleosporium montanum* host plants/species affected

Host status	Host name	Plant family	Common name	Reference
Cultivated hosts	*Symphyotrichum lanceolatum*	Asteraceae	Lance-leaved aster	Voglmayr et al. (2020)
	Symphyotrichum novae-angliae	Asteraceae	Hairy michaelmas daisy	Voglmayr et al. (2020)

Appendix C – *Coleosporium solidaginis* host plants/species affected

Host status	Host name	Plant family	Common name	Reference
Cultivated hosts	*Aster spp.*	Asteraceae	–	Hodson and Christensen (1949)
	Aster prenanthoides	Asteraceae	–	Hunt (1929)
	Liatris pycnostachya	Asteraceae	–	Luecke and Crawford (2019)
	Pinus contorta	Asteraceae	Lodgepole pine	Weir (1925)
	Pinus echinata	Asteraceae	Shortleaf pine	Hedgcock and Hunt (1922a, 1922b)
	Pinus ponderosa	Asteraceae	Ponderosa pine	Dos Santos and Da Cámara (1954)
	Pinus rigida	Asteraceae	Pitch pine	Graff (1947)
	Solidago spp.	Asteraceae	–	Hodson and Christensen (1949)
	Solidago altissima	Asteraceae	–	Harada (1994)
	Solidago canadensis	Asteraceae	Canadian goldenrod	Hills (1942)
	Solidago gigantea	Asteraceae	–	Harada (1994)
	Solidago hispida	Asteraceae	–	Graff (1947)
	Solidago neglecta	Asteraceae	–	Graff (1947)
	Solidago rugosa	Asteraceae	–	Hedgcock and Hunt (1922a, 1922b)
	Solidago virgaurea	Asteraceae	–	Shin et al. (2018)

Appendix D – Distribution of *Coleosporium asterum*

Region	Country	Subnational (e.g. State)	Status	References
Asia	China	Gansu	Present, no details	Zhuang and Wang (2006)
		Zhejiang*	Present, no details	Wang et al. (2017)
	Japan		Present, no details	McTaggart and Aime (2018)
		Aichi	Present, no details	Hiratsuka et al. (1990)
		Ibaraki*	Present, no details	Sjamsuridzal et al. (1999)
		Shizuoka	Present, no details	Hunt (1929)
		Tokyo	Present, no details	Hiratsuka et al. (1990)
	India	Nalanda	Present, no details	Sinha and Singh (2012)
	South Korea		Present, no details	Park et al. (2012)
		Kwangju	Present, no details	Yi et al. (1982)
		Pocheon*	Present, no details	Back et al. (2014)
		Ulleong-Do*	Present, no details	Back et al. (2014)
		Yongin*	Present, no details	Kim et al. (2017)
	Taiwan	Ku-Kuan	Present, no details	Berndt (1996)
EU	France		Present, no details	Bru-Adan et al. (2009)
	Germany		Absent, invalid record	pers. comm. from NPPO (2023)
	Spain		Absent, unreliable record	pers. comm. from NPPO (2023)
	Portugal		Present: not widely distributed and not under official control	pers. comm. from NPPO (2023)
Other Europe		**Azores***	Present, no details	Talhinhas et al. (2019)
		Madeira*	Present, no details	Talhinhas et al. (2019)
	Switzerland		Present, no details	Kruse et al. (2017)
North America	Canada	Alberta	Present, no details	Lowe (1972)
		British Columbia	Present, no details	Lowe (1972)
		Manitoba	Present, no details	Lowe (1972)
		New Brunswick	Present, no details	Mihail et al. (2002)
		Northwest territories	Present, no details	Suzuki et al. (2018)
		Ontario	Present, no details	Mains (1937)
		Quebec	Present, no details	McTaggart et al. (2018)
		Saskatchewan	Present, no details	Lee et al. (2018)
		Yukon	Present, no details	Lee et al. (2018)
	USA	Illinois	Present, no details	Price et al. (2004)
		Indiana	Present, no details	Price et al. (2004)
		Michigan	Present, no details	Price et al. (2004)
		Minnesota	Present, no details	Sjamsuridzal et al. (1999)
		Ohio	Present, no details	Price et al. (2004)
		Pennsylvania	Present, no details	Price et al. (2004)
		Wisconsin	Present, no details	Price et al. (2004)

*: Confirmed by molecular findings.

Appendix E – Distribution of *Coleosporium montanum*.

Region	Country	Subnational (e.g. State)	Status	References
Asia	**South Korea***		Present, no details	Beenken et al. (2017)
North America	**USA***	**Indiana***	Present, no details	Beenken et al. (2017)
		Illinois*	Present, no details	Beenken et al. (2017)
		Maryland*	Present, no details	Beenken et al. (2017)
		Minnesota*	Present, no details	Beenken et al. (2017)
		New York*	Present, no details	Beenken et al. (2017)
		North Carolina*	Present, no details	Beenken et al. (2017)
		North Dakota*	Present, no details	Beenken et al. (2017)
		Washington*	Present, no details	Beenken et al. (2017)
	Canada*	**Quebec***	Present, no details	Beenken et al. (2017)
		Newfoundland and Labrador*	Present, no details	Beenken et al. (2017)
EU	**Austria***	**Baumgarten an der March***	Present, no details	Voglmayr et al. (2020)
		Sankt Willibald*	Present, no details	Voglmayr et al. (2020)

*: Confirmed by molecular findings.

Appendix F – Distribution of *Coleosporium solidaginis*

Region	Country	Subnational (e.g. State)	Status	References
Asia	**Japan***		Present, no details	McTaggart and Aime (2018)
		Hokkaido	Present, no details	Harada (1984)
North America	Canada		Present, no details	Nicholls et al. (1976)
	USA	**Florida***	Present, no details	McTaggart and Aime (2018)
		Idaho		Weir (1925)
		Louisiana*	Present, no details	McTaggart and Aime (2018)
		Maryland*	Present, no details	McTaggart and Aime (2018)
		Michigan	Present, no details	Baxter (1931)
		Minnesota	Present, no details	Hodson and Christensen (1949)
		Mississippi*	Present, no details	McTaggart and Aime (2018)
		Montana	Present, no details	Weir (1925)
		New Jersey*	Present, no details	McTaggart and Aime (2018)
		New York*	Present, no details	McTaggart and Aime (2018)
		North Carolina*	Present, no details	McTaggart and Aime (2018)
		Oregon		McTaggart and Aime (2018)
		Pennsylvania*	Present, no details	McTaggart and Aime (2018)
		Tennessee*	Present, no details	McTaggart and Aime (2018)
		Texas*	Present, no details	Luecke and Crawford (2019)
		Virginia*	Present, no details	Graff (1947), Hedgcock (1922)
		Washington	Present, no details	Weir (1925)
EU	**Germany***		Present, no details	McTaggart and Aime (2018), confirmed by pers. comm. from NPPO (2023)
Other Europe	**Switzerland***		Present, no details	McTaggart and Aime (2018)
		Ticino*	Present, no details	Beenken et al. (2017)

*: Confirmed by molecular findings.