EPPO Datasheet: *Cronartium fusiforme*

Last updated: 2024-09-16

IDENTITY

Preferred name: *Cronartium fusiforme*
Authority: Peck ex Hedgcock & N.R. Hunt
Taxonomic position: Fungi: Basidiomycota: Pucciniomycotina: Pucciniomycetes: Pucciniales: Cronartiaceae
Other scientific names: *Cronartium quercuum f. sp. fusiforme* Burdsall & Snow, *Peridermium fusiforme* Arthur & F. Kern
Common names: Southern fusiform rust of pine, fusiform rust of Southern pines, fusiform rust of pine, rust of oak
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EPPO Categorization: A1 list
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EPPO Code: CRONFU



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Notes on taxonomy and nomenclature

Cronartium fusiforme Peck ex Hedgc. & N.R. Hunt is validly published as '(Peck) Hedgc. and Hunt., comb. nov.', by reference to the description of *Peridermium fusiforme* Arthur & F. Kern (Arthur and Kern, 1906). The validation made by Cummins (1956) as *C. fusiforme* Cummins, is not appropriate and should be considered as a synonym.

Over the years, different names have been used for the causal agent of fusiform rust. In 1977, Burdsall and Snow concluded that, as the fungus was primarily pathogenic on *Pinus taeda* (loblolly pine) and *Pinus elliottii* (slash pine), and no consistent morphological difference could be found between *Cronartium quercuum* (Berk.) Miyabe ex Shirai and *C. fusiforme*, the latter should be considered as a *forma specialis* of *C. quercuum*. As clarified by Hiratsuka (1995), the term *forma specialis* can be used when no morphological differences exist, but host specificities are different. However, Kuhlman and Kaneko (1991) found minor morphological differences among the different *formae speciales* of *C. quercuum*. More recently, Zhao *et al.* (2022) observed unique morphological features for *C. fusiforme*, and multigene molecular phylogeny analysis showed that *C. fusiforme* formed a well-supported clade distinct from *C. quercuum*, thus supporting the fact that the fungus should not be considered as a *forma specialis*, but as a distinct species.

HOSTS

To complete its life cycle, *C. fusiforme* alternates between its aecial hosts (*Pinus* spp. – primary hosts), and telial hosts (*Quercus* spp. – secondary hosts).

The aecial hosts of *C. fusiforme* are two- -and three-needled *Pinus* spp., of which the most economically important in North America are the Southeastern species slash pine (*P. elliottii*) and loblolly pine (*P. taeda*). Other species that are occasionally attacked include pitch pine (*P. rigida*) and pond pine (*P. serotina*).

Though some *Pinus* species are resistant (e.g. red pine, *P. resinosa*; jack pine, *P. banksiana*), practically all can be experimentally infected to a certain extent. In an experimental study of seedlings of 45 *Pinus* species from North America, Central America, the Caribbean, Asia and the Euro-Mediterranean region, all but one (*P. resinosa*) showed some infection, and 12 species were more susceptible than *P. elliottii* (Tainter & Anderson, 1993). Of particular interest for the EPPO region was the fact that the fairly widely planted North American species lodgepole pine (*P. contorta*), western yellow pine (*P. ponderosa*) and Monterey pine (*P. radiata*) were all susceptible. Important European species which were relatively susceptible included Canary island pine (*P. canariensis*), Aleppo pine (*P. halepensis*), some forms of *P. nigra*, and umbrella pine (*P. pinea*). Mountain pine (*P. mugo*) and maritime pine (*P. pinaster*) were less susceptible. Scots pine (*P. sylvestris*) was not tested in these experiments, but is considered as a host by Zhao *et al*. (2022). Species from Central America, the Caribbean and Asia were also susceptible.

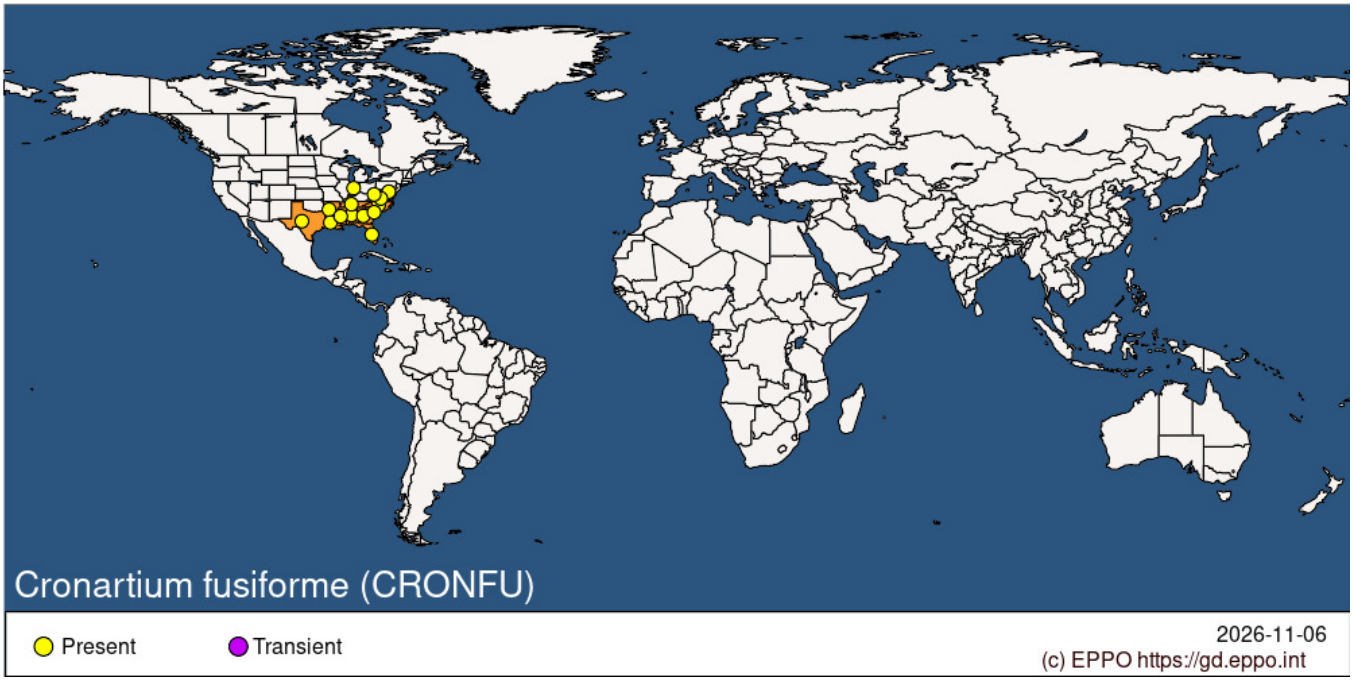
The telial hosts of *C. fusiforme* are mainly *Quercus* spp., of the red oak group and generally not the white oak group. Typical host species are water oak (*Q. nigra*) and willow oak (*Q. phellos*). North American *Castanea* spp. (such as *C. dentata*) and *Castanopsis* spp. have also been recorded as hosts from the USA (MyCoPortal, 2024), but their host status needs to be further verified considering the more recent changes in taxonomy.

For more information, see Spaulding (1956, 1961), Boyce (1961), USDA (1963), Davidson & Prentice (1967), Peterson (1967), Hepting (1971), Ziller (1974), Zhao *et al*. (2022).

Host list: *Castanea dentata, Pinus caribaea, Pinus cooperi, Pinus echinata, Pinus elliottii, Pinus massoniana, Pinus nigra, Pinus palustris, Pinus pseudostrobus, Pinus rigida, Pinus serotina, Pinus sylvestris, Pinus taeda, Quercus emoryi, Quercus fabri, Quercus falcata, Quercus incana, Quercus kelloggii, Quercus laevis, Quercus laurifolia, Quercus lyrata, Quercus marilandica, Quercus nigra, Quercus pagoda, Quercus palustris, Quercus phellos, Quercus serrata, Quercus variabilis, Quercus velutina, Vincetoxicum nigrum*

GEOGRAPHICAL DISTRIBUTION

Cronartium fusiforme is endemic to the South-Eastern United States and is the most economically damaging fungal disease of pine trees in this region. The fungus has recently been found on old herbarium specimens from East Asia (China, Japan) and Northern Europe (Sweden on *Vincetoxicum nigrum*) (Zhao *et al*., 2022). However, the presence of *C. fusiforme* in those countries still needs to be confirmed.



North America: United States of America (Alabama, Arkansas, District of Columbia, Florida, Georgia, Indiana, Louisiana, Maryland, Mississippi, North Carolina, South Carolina, Tennessee, Texas, Virginia, West Virginia)

BIOLOGY

Spermogonia and aecia are produced in the spring and early summer, one to several years after infection of the aecial hosts (*Pinus* spp.). Aeciospores, produced in the aecia, are windborne and may be carried over long distances. These spores cannot re-infect the aecial host on which they are produced but can infect the telial host (*Quercus* spp). Approximately two weeks after infection of the telial host by aeciospores, uredinia develop on the abaxial leaf surface. Uredinia are produced throughout the summer and urediniospores produced therein reinfect the telial hosts. Urediniospores are windborne and may be carried over long distances. Telia are produced in late summer and the teliospores germinate in place to produce basidiospores (Sinclair and Lyon, 2005). Basidiospores are sensitive to

drying and solar radiation and mostly released during night time (Sinclair and Lyon, 2005). Dispersal is usually limited to an area within 1.5 km of the telial host.

The windborne basidiospores infect the first-year pine needles during summer and autumn (Sinclair and Lyon, 2005). Host infection occurs by direct penetration of the branches or stems, following basidiospore germination. This results in the production of spindle, or fusiform, shaped swellings that are typical for this rust. The time between infection of the aecial hosts and the formation of spermogonia ranges from several weeks to more than two years. Cross-fertilisation of the spermogonia occurs through hyphal anastomoses (Schmidt and Miller, 1999) or by insects (Sinclair and Lyon, 2005). Spermogonia on the aecial hosts are produced on the galls on branches and stems. After several weeks (up to one year), aecia are produced where spermogonia previously appeared, producing yellow to orange aeciospores (Sinclair and Lyon, 2005). The aeciospores have thick walls, tolerate U.V. light and desiccation and can disperse over long distances.

The fungus overwinters in branches, stems and galls of *Pinus* spp. The fungus is perennial in pine tissue after infection and grows into the outer rings of sapwood (Sinclair and Lyon, 2005).

In experiments, basidiospores of *C. fusiforme* demonstrated *in vitro* germination within a 24-hour timeframe at temperatures ranging from 8 to 32°C. Notably, at 32°C, only short germ tubes were observed. Germination was observed between 12 to 28°C, with 90% of maximum germination occurring at temperatures spanning 14.6 to 29.6°C. When subjected to moist incubation for 24 hours at 11.6 to 23.4°C, a 90% maximum infection rate was achieved in susceptible pine seedlings. The basidiospores exhibited the ability to initiate infections across a broad temperature spectrum of 8 to 28°C during the 24-hour period of moist incubation (Kuhlman and Pepper, 1994).

Artificial inoculation of *P. eliliotii* (slash pine) seedlings with basidiospores of *C. fusiforme* showed that the fungal hyphae produced an infection peg that penetrated through cuticle and cell walls of epidermal cells of hypocotyls, cotyledons, stems and primary and secondary needles. Appressoria were rarely formed by the fungus (Miller *et al*., 1980). Following penetration, there is rapid and profuse colonization of the mesophyll and endodermis, resulting in partial to complete host-cell dissolution. Schmidt *et al.* (1988) have analysed the site factors which favour fusiform rust in young plantations and found that rust incidence was greatest on sites well-drained soils than poorly drained. The widely distributed and much studied *C. ribicola* has similar biology.

Genomic resources are now available for fusiform rust. The complete genome was sequenced and revealed gene gain and gene losses associated with the biotrophic lifestyle of the pathogen (Pendleton *et al*., 2014).

DETECTION AND IDENTIFICATION

Symptoms

On *Pinus*, typical spindle-shaped, elongate stem and branch galls form, growing at a rate of 7-12 cm annually. Old infections develop into sunken cankers, while seedling infection results in a witches' broom appearance. On the alternate host, *Quercus*, inconspicuous leaf spots occur and telia can be observed. Only in cases of extremely severe infection will oak leaf abscission be observed.

Morphology

Aecia caulicolous, erumpent from the bark, on trunks or branches, usually with spindle-shaped or variously elongated galls, partial bark collars presence at the edge of galls, peridia are two to several cells thick, peridial cells ellipsoid or linear, 58–117 × 15–27 ?m, wall coarsely verrucose, aeciospores subglobose, ellipsoid, oblong, or fusoid, or sometimes pointed 17–45 × 15–27 ?m (average dimensions 28 × 19), walls are 2.5–6.5 ?m thick (mostly 3–5 ?m), coarsely verrucose, warts annulate, 1–2 annuli, variable in shape, cylindrical, or joined to form ridges or appearing labyrinthine, with small bumps on top. Uredinia hypophyllous, minute, scattered, 0.2–0.4 mm in diameter, uredinial paraphyses present, urediniospores oval, broadly ellipsoid, obovate, 14–33 × 13–22 ?m, wall hyaline, 2–2.5 (–3) ?m thick, echinulate, germ pores mostly scattered, inconspicuous. Telia hypophyllous, cylindrical to filiformis (with hair-like columns), 1.2–3.5 mm long, straight or slightly curved, bright yellow, cross-section of telia with 7–10 teliospores, teliospores oblong, 25–54 × 10–21 ?m, catenulate, wall colorless, 2.5–5.5 ?m thick, without surface

ornamentation (Cummins 1956; Peterson 1967, Zhao *et al*., 2022).

Detection and inspection methods

Random amplified polymorphic DNA markers may be used to "fingerprint" individual isolates of *C. fusiforme* (Doudrick *et al*., 1993a; 1993b). In a phylogenetic tree based on three nuclear ribosomal RNA gene regions, i.e., the internal transcribed spacer regions and intervening 5.8S nrRNA gene (ITS), the large subunit (LSU) and the small subunit (SSU) rDNA, *C. fusiforme* formed a well-supported clade distant from *C. quercuum* (Zhao *et al*., 2022). Two *Cronartium* genus PCR assays can be used for the detection of multiple species of phytosanitary concern, including *C. quercuum, C. coleosporioides, C. comandrae, C. comptoniae, C. fusiforme* and *C. ribicola* (Bergeron *et al*., 2019).

PATHWAYS FOR MOVEMENT

Cronartium spp. can be carried over considerable distances as wind-borne aeciospores (e.g. more than 400 km for *C. ribicola;* Maloy, 2003) and can survive considerable periods in the airborne state (Chang & Blenis, 1989). More importantly, these rusts can be carried to new areas on plants for planting of their coniferous hosts, as has occurred in parts of the USA. The long incubation periods of *Cronartium* rusts mean that latent infections easily go undetected unless post-entry quarantine is applied. As *Cronartium* spp. require live host tissues to survive, the risks associated with movement of non-squared coniferous wood seems to be limited (EFSA, 2018). As the alternate hosts of *C. fusiforme* are deciduous and infection is restricted to the leaves, there should be no risk in shipment of dormant material. Similarly, there is no known risk in movement of *Pinus* seeds or pollen.

PEST SIGNIFICANCE

Economic impact

The *Cronartium* rusts cause very important diseases throughout the world, resulting in malformation, reduced vigour and death of trees and seedlings. However, their abundance depends primarily on the abundance of the telial host (Gross *et al*., 1983). *C. fusiforme* causes the most serious forest-tree disease in the Southern USA, especially on *P. taeda* and *P. elliottii,* attacking *Pinus* immediately after germination onwards (damage to *Quercus* is insignificant). Stem-girdling galls are particularly damaging (Walkinshaw & Roland, 1990). The disease can kill young pines (1-to 5-year-old), and increases potential wind breakage of older trees. Much more information is published on this *Cronartium* species than on all the North American *Cronartium* spp. of conifers put together. Fusiform rusts infection on economically valuable loblolly pine (*P. taeda*) and slash pine (*P. elliottii*) and *P. palustris* in South-Eastern US cause over 140 million USD annual estimated economic losses (Wijesinghe *et al*., 2019). Equations have been developed to predict survival of *Pinus elliottii* infected by fusiform rust (Devine & Clutter, 1985). For more information on the pest significance of *Cronartium* spp., see also Boyce (1961), Peterson & Jewell (1968), Ziller (1974), Sinclair *et al*. (2005).

Control

The best control strategy for fusiform rust is through breeding and selection for resistance. Fortunately, genetic rust resistance is relatively abundant in the commercially important slash and loblolly pines in the USA. This has become the foundation for the management of the disease (Schmidt, 2003). Rust resistant parents are established in seed orchards seedlings from open-pollinated resistant parent trees or from control matings (full-sibs) have been deployed over millions of acres of forest plantations, especially in high-rust-hazard areas. A variety of options are available to land managers who can utilize some unique resistant genotypes in very large plantings (narrow genetic base, but durable resistance) in relatively short rotations (Sniezko, 2014). Additional control measures include the removal of infected material, in particular in nurseries. Eradicating the alternate host is not a practical possibility. Nurseries should be located away from possible infection sources. Chemicals can be used as seed treatments or as sprays (Runion *et al*., 1991; Carey & Kelley, 1994; Haywood *et al*., 1994). Research into resistant cultivars and systemic fungicides has led to successful control, especially of *C. fusiforme* in forest nurseries (Powers, 1984). Triadimefon fungicide treatments significantly minimized rust-related damage in pine plantations. This led to increased survival rates, a reduced occurrence of stem galls in trees, fewer galls below 5 feet of tree height (1.5 m), a decreased

presence of trees with galls encircling 76-100% of the stem, higher total volume per acre, and a smaller volume among trees affected by the infection (CABI, 2019). Carey and Kelley (1994) examined the effectiveness of cyproconazole seed treatment and foliar sprays in managing *C. fusiforme* on loblolly pine (*Pinus taeda*) seedlings. The investigation involved greenhouse trials in North Carolina and nursery trials in Alabama. Results from the nursery trials revealed a significant percentage (54%) of untreated seedlings exhibiting gall formation at lifting. Conversely, no galls developed on seedlings treated with the lowest rate of cyproconazole foliar spray without the seed treatment, and only 0.1% of seedlings treated solely with the seed treatment exhibited gall formation. Laboratory inoculations demonstrated that cyproconazole seed treatments remained effective for at least 20 and 30 days, respectively, while foliar sprays were effective for 14 days but not for 21 days.

Phytosanitary risk

The risk presented by non-European *Cronartium* spp. to the EPPO region is classically exemplified by reference to the quarantine pest *C. ribicola* (Phillips, 1988), which has made it almost impossible to grow *P. strobus* commercially in most areas in Europe and North America to which the fungus was introduced from Asia. *C. fusiforme* is the most important *Cronartium* sp. on Southern pines (*P. elliottii, P. taeda*) in North America at the present time, and though its main North American hosts are not grown commercially in the EPPO region, other North American hosts are widely planted in parts of the EPPO region. Some European, and especially Mediterranean, *Pinus* species have proved experimentally susceptible.

It should, however, be stressed that the potential risk from introduced *Cronartium* spp. to pines is much affected by the prevalence of the telial hosts, mainly *Quercus* spp. No information seems to be available on the susceptibility of European species of these genera. The most widespread European oak species are "white oaks" (subgenus *Quercus*), and thus belong to the group which is not susceptible to *C. fusiforme* in North America. North American red oaks are planted to a limited extent in Europe (e.g. *Q. rubra*, but not the main southeastern species).

The European evergreen oaks (e.g. *Q. ilex*) could be susceptible, but there is no direct evidence of this. Kuhlman & Matthews (1993) mention propagation of single-aeciospore isolates of *C. fusiforme* on the Asian species *Q. acutissima*. Tainter & Anderson (1993) mention that the Californian *Q. kelloggii* is as susceptible as the Southeastern *Q. nigra*, and imply that the propensity of *C. fusiforme* to attack "exotic" aecial hosts could be matched by a similar propensity to attack "exotic" telial hosts.

Cronartium fusiforme is a very serious disease in North America. Several European species of *Pinus* have been experimentally shown to be susceptible (but not *P. sylvestris* and only to a limited extent *P. pinaster*). Several widely planted North American species are susceptible. No European species have been specifically recorded as a telial host and North American red oaks are planted in Europe to only a rather limited extent. Accordingly, *C. quercuum* can be considered to present a risk for the EPPO region, but one which would be much more clearly defined if the status of European *Quercus* spp. as potential telial hosts were systematically examined.

PHYTOSANITARY MEASURES

Since symptoms may not be apparent for many years after infection, the only practical safeguard is to prohibit entry of the *Pinus* hosts plants for planting from countries where *C. fusiform* occurs. Other phytosanitary measures could require that these plants are produced in pest-free areas or pest free places of production (with their immediate vicinity also free from the pests during the last growing season) (EPPO, 2010, 2017a & 2017b). *Quercus* spp. should only be imported in a dormant state, without leaves. Wood of *Pinus* should originate from pest-free areas, or should be debarked or should have been appropriated treated (EPPO 2017ab, 2010).

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Datasheet history

This datasheet was first published in the EPPO Bulletin in 1979 (as part of the non-European *Cronartium* spp.) and revised in the two editions of 'Quarantine Pests for Europe' in 1992 and 1997, as well as in 2023. It is now maintained in an electronic format in the EPPO Global Database. The sections on 'Identity', ‘Hosts’, and 'Geographical distribution' are automatically updated from the database. For other sections, the date of last revision is indicated on the right.

CABI/EPPO (1992/1997) *Quarantine Pests for Europe (1st and 2nd edition)*. CABI, Wallingford (GB).

EPPO (1979) Data sheets on quarantine organisms No. 9, *Cronartium* spp. (non-European). *EPPO Bulletin* **9**(2), 47-60. https://doi.org/10.1111/j.1365-2338.1979.tb02450.x



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