

EPPO Datasheet: *Pucciniastrum minimum*

Last updated: 2023-03-28

IDENTITY

Preferred name: *Pucciniastrum minimum*

Authority: (Schweinitz) Arthur

Taxonomic position: Fungi: Basidiomycota: Pucciniomycotina:
Pucciniomycetes: Pucciniales: Pucciniastraceae

Other scientific names: *Peridermium peckii* Thümen, *Thekopsora minima* (Arthur) Sydow & P. Sydow, *Uredo azaleae* (Schweinitz) Saccardo, *Uredo minima* Schweinitz

Common names: blueberry rust, leaf rust of blueberry

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EPPO Categorization: A2 list

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EU Categorization: RNQP ((EU) 2019/2072 Annex IV)

EPPO Code: THEKMI



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Notes on taxonomy and nomenclature

The taxonomic placement of *Pucciniastrum minimum* has changed several times and is quite uncertain. This rust fungus was for a long time considered to be one of two different forms of a fungus known at the time as *Pucciniastrum vaccinii* (Sato *et al.*, 1993). Following morphological studies, the complex was split into two species: *Naohidemyces vacinii* and *Thekopsora minima* (Sato *et al.*, 1993). However, phylogenetic analysis has shown that the latter belongs to the genus *Pucciniastrum*, and the appropriate name should then be *P. minimum* (Padamsee and McKenzie, 2014, 2019; Aime and McTaggart, 2021). Nevertheless, further taxonomic revisions may occur as Scholler *et al.* (2022) suggest that the species should be transferred to another genus, but that additional studies are required.

Due to the previous taxonomic assignment of the species as part of a species complex, most of the literature about the fungus should be interpreted carefully. The previous name *Thekopsora minima* is still commonly used and *P. vaccinii* sensu lato frequently appears to be used in the USA and Canada (University of Georgia, 2015; EPPO, 2017b).

HOSTS

The aecial stage of the fungus is found on some species of *Tsuga* (hemlock). Three hemlock species have been reported to host the aecial stage of the fungus, i.e., *Tsuga canadensis*, *Tsuga diversifolia* and *Tsuga sieboldii*.

The uredinial and telial stages are found on different genera and species belonging to the family Ericaceae. Several species of *Vaccinium* are considered major hosts, i.e., *V. angustifolium*, *V. corymbosum*, *V. erythrocarpum* and *V. virgatum*. The fungus has also been successfully inoculated on other *Vaccinium* species and hybrids, e.g., *V. tenellum*, *V. pallidum*, *V. elliotti*, *V. corymbosum* x *V. pallidum* and *V. elliottii* x *V. pallidum* (Babiker *et al.*, 2018). *Vaccinium myrtillus*, a native blueberry species in the EPPO region, has also been successfully infected in experimental conditions (Latham *et al.*, 2021). No infections on *V. myrtillus* have been observed so far in the field (e.g., Wichura *et al.*, 2020; Schrader *et al.*, 2021). The susceptibility to infection by the fungus varies between *Vaccinium* species and inoculation experiments suggest that *Vaccinium arboretum* is immune to infection (Babiker *et al.*, 2018).

Other Ericaceous host species belong to the genera *Gaylussacia* (huckleberry), *Lyonia*, *Menziesia* and *Rhododendron* (which includes rhododendron and azaleas) (Sato *et al.*, 1993; Farr and Rossman, 2023).

Host list: *Gaylussacia baccata*, *Gaylussacia frondosa*, *Lyonia ovalifolia*, *Menziesia pilosa*, *Rhododendron canadense*, *Rhododendron canescens*, *Rhododendron lutescens*, *Rhododendron ponticum*, *Rhododendron prunifolium*, *Rhododendron viscosum*

, *Tsuga canadensis*, *Tsuga diversifolia*, *Tsuga sieboldii*, *Vaccinium angustifolium*, *Vaccinium ashei*, *Vaccinium corymbosum*, *Vaccinium darrowii*, *Vaccinium erythrocarpum*, *Vaccinium virgatum*

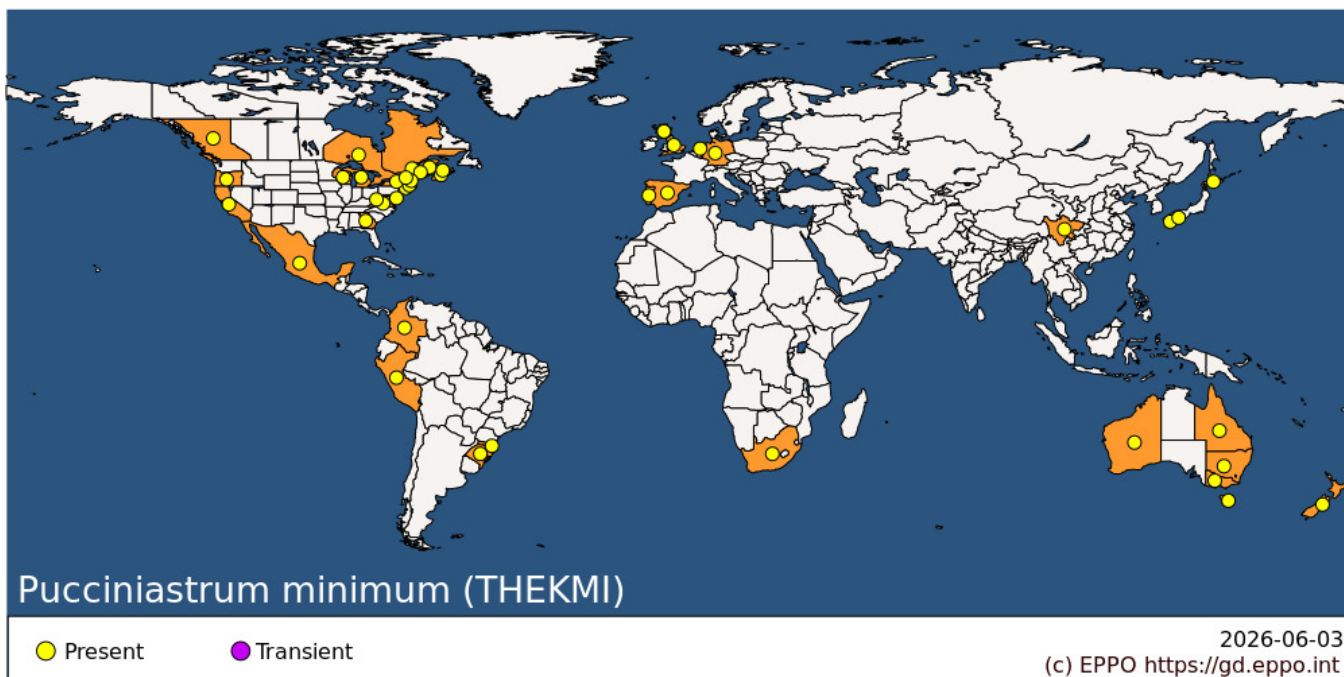
GEOGRAPHICAL DISTRIBUTION

The native range of the rust fungus is thought to be north-eastern North America (Wichura *et al.*, 2020; Anderson, 2022). The fungus has also been observed for a long time in Japan and was only known from these two regions until 1993 (Sato *et al.*, 1993). Since then, the rust fungus has been detected in many more countries and is now reported from all continents except Antarctica.

In North America, the fungus was previously reported only in the north-eastern parts (Sato *et al.*, 1993; Anderson, 2022), but was then detected in Mexico in 2007 (Rebollar-Alviter *et al.*, 2011), and on the west coast of the United States in Oregon in 2015 (Wiseman *et al.*, 2016) and California in 2017 (Shands *et al.*, 2018). In South America the fungus was detected in Colombia in 2011 (Salazar & Buriticá, 2012), Brazil in 2017 (Pazdiora *et al.*, 2019), and Peru in 2018 (Huarhua *et al.*, 2020).

In Oceania, the fungus was first observed in New Zealand in 2004 (Padamsee and McKenzie, 2019) and in 2012 it was detected in Queensland, Australia (McTaggart *et al.*, 2013). Since then it has also been found in several other Australian states and territories, i.e., New South Wales, Tasmania, Victoria and Western Australia (Government of Western Australia 2022). In Africa the fungus was reported from South Africa in 2006 (Mostert *et al.*, 2010). In Asia, apart from being present in Japan, the fungus is now also present in Sichuan, China (Zheng *et al.*, 2017).

In the EPPO region, *Pucciniastrum minimum* was first officially detected in Germany in 2015, but further investigations of herbarium material showed that the fungus was present already in 2011 (Wichura *et al.*, 2020). Following the discovery of the fungus in Germany it was subsequently reported from Belgium, the Netherlands, Portugal, Spain, the United Kingdom and Sweden (EPPO 2016, 2017a, 2022a). In Belgium and Sweden, the fungus was found in nurseries and on imported plants and has since been eradicated (EPPO, 2021, 2022a). Possibly the fungus was present in Europe even earlier since it has been suggested that reports of *P. vaccinii* causing blueberry rust in Spain in 1997 (Barrau *et al.*, 2022) were based on a misidentification and the fungus may have been *P. minimum* (Wichura *et al.*, 2020). Such misidentification may apply also to other reports (Anderson, 2022), and the geographic distribution of *P. minimum* is thus uncertain.



EPPO Region: Germany, Netherlands, Portugal (mainland), Spain (mainland), United Kingdom (England, Scotland)

Africa: South Africa

Asia: China (Sichuan), Japan (Hokkaido, Kyushu, Shikoku)

North America: Canada (British Columbia, New Brunswick, Nova Scotia, Ontario, Prince Edward Island, Québec),

Mexico, United States of America (California, Connecticut, Delaware, Georgia, Maine, Massachusetts, Michigan, New Hampshire, New York, Oregon, Vermont, Virginia, West Virginia, Wisconsin)

South America: Brazil (Rio Grande do Sul, Santa Catarina), Colombia, Peru

Oceania: Australia (New South Wales, Queensland, Tasmania, Victoria, Western Australia), New Zealand

BIOLOGY

Pucciniastrum minimum is a heteroecious rust fungus requiring two different plant hosts to fulfill its life cycle, which is as follows (c.f. Sinclair and Lyon, 2005; Miles *et al.*, 2020; Simpson, 2021c). The fungus overwinters in leaves of the ericaceous hosts as telia. In early spring teliospores are formed and germinate in the leaves, producing basidiospores that infect the needles of *Tsuga* spp. Aecia are formed in the needles and the released aeciospores infect the ericaceous hosts in early summer. Uredinia develop on the leaves of the ericaceous hosts and the urediniospores produced spread the fungus to re-infect new leaves and new plants. Uredinia and urediniospores are produced as long as the conditions are conducive, i.e., warm and moist, and multiple infection cycles can occur in a season (Simpson, 2021a).

In areas where *Tsuga* spp. are not present, *P. minimum* appears to survive from year to year on the ericaceous host only, especially in hosts that retain their leaves over winter (Babiker *et al.*, 2018). In evergreen systems in Australia, the fungus is found in leaves throughout the year and is able to form urediniospores to re-infect *Vaccinium* plants when the conditions become conducive (Simpson, 2021a). However, the fungus is also reported to be able to persist in Germany where the *Vaccinium* hosts are deciduous (Wichura *et al.*, 2020). Observational studies of *V. corymbosum* found no evidence of systemic infection of buds, but that only leaves exposed to airborne urediniospores were infected and it is suggested that urediniospores could overwinter (Wichura *et al.*, 2020).

Pucciniastrum minimum can infect plants of all ages (EFSA *et al.*, 2020). Younger *Vaccinium* leaves are however more susceptible to infection as the cuticle of older leaves is more difficult for the fungus to penetrate (Simpson, 2021a). High humidity and warm temperatures are conducive for infection of urediniospores. Simpson (2021a) report that under 100% humidity spores grow at temperatures between 5 and 30°C with optimum temperatures for spore germination being 15-25°C. Pfister *et al.*, (2004) observed optimum temperatures of 19-23°C for germination. At least 7 hours of leaf wetness is required for infection at 24°C (Simpson, 2021a).

The latency period has been estimated to be 11 days in *Rhododendron*, i.e., uredinia production after inoculation and incubation in the lab at 20°C (Pfister *et al.*, 2004). Simpson (2021a) reports a latency period of 10-12 days depending on the temperature. The latency period appears to differ between varieties of *V. corymbosum* (Wichura *et al.*, 2020).

DETECTION AND IDENTIFICATION

Signs and Symptoms

Symptoms are found mainly on the leaves. However, infection of stems, flowers and fruits of *Vaccinium* plants has also been observed (Simpson, 2021a). The first symptoms of infection of *Vaccinium* hosts are small yellow lesions on the upper side of the leaves, becoming darker as the disease progresses and turning into brown necrotic spots (Simpson, 2021a). Uredinia are visible as yellow-orange pustules on the lower side of the leaves (Schilder and Miles, 2011). The spores are powdery and when numerous they can be seen suspended in air currents (Simpson, 2021a). Under favourable conditions (for the fungus), disease symptoms may increase rapidly late in the season (Schilder 2014; Miles *et al.*, 2020). Defoliation may occur when infection levels are high (Simpson, 2021a).

Infection of *Tsuga* hosts causes yellowing and premature shedding of needles (Sinclair and Lyon, 2005).

Morphology

Aecia, found on *Tsuga* hosts, are cylindrical, light cream coloured and arranged along the two rows of stomata on the underside of the needles and aeciospores are subglobose, measure 18-26 x 15-18 µm and are ornamented with densely studded, short, blunt, rodlike protuberances (Sato *et al.*, 1993; Sinclair and Lyon, 2005). Uredinia, formed on the ericaceous hosts, are dome-shaped and found on the underside of the leaves and urediniospores are yellow-

orange, ellipsoid to oblong, evenly spiny and measure 20-24 x 12-18 µm (Sato *et al.*, 1993; Sinclair and Lyon, 2005). Telia develop intraepidermally and teliospores consist of 2-8 laterally adhering cells measuring 20-35 x 18-32 µm as seen in surface view (Sato *et al.*, 1993).

For further details see Sato *et al.* (1993) and Sinclair and Lyon (2005).

Detection and inspection methods

Symptoms on the leaves of the *Vaccinium* hosts are easily recognized as being caused by a rust fungus when the yellow-orange pustules on the lower surface of the leaves are visible (Schrader and Maier, 2015). To observe symptoms a hand lens with 10-20x magnifications is useful (EFSA *et al.*, 2020). Infected plants may, however, go undetected during the latency period when no symptoms are visible (Simpson, 2021a).

Similar symptoms may also be caused by other rust fungi. Other species of rust fungi found infecting the leaves of *Vaccinium* spp. and the needles of *Tsuga* spp. are *Naohidemyces vaccinii*, which is present in the EPPO region and *N. fujisanensis*, which is restricted to Japan (Sato *et al.*, 1993; Padamsee and McKenzie, 2019). *Pucciniastrum hydrangea* (syn. *Thekopsora hydrangea*) is another rust fungus with similar aecia found on *Tsuga* (e.g. *T. canadensis*) but the alternate host is *Hydrangea* sp. (Sinclair and Lyon, 2005). The latter rust fungus is reported from the Eastern USA and Japan (Farr and Rossman, 2023).

According to the literature, *P. minimum* can be distinguished from these species based on morphological characteristics of the aecial and/or telial stages (Sato *et al.*, 1993; Sinclair and Lyon, 2005; McTaggart *et al.*, 2013). The differences in the uredinia between the species are however small. Specific experience on sample preparation and interpretation of morphological characters of rust fungi are required (EPPO 2017b; EFSA *et al.*, 2020). For reliable identification molecular identification methods are required (EPPO 2017b; EFSA *et al.*, 2020). Identification is mainly done by molecular analysis of different sequences of the ITS-LSU region of the DNA (e.g. McTaggart *et al.*, 2013; Padamsee and McKenzie 2019; Wichura *et al.*, 2020; Latham *et al.*, 2022).

PATHWAYS FOR MOVEMENT

The spores are airborne and natural spread can occur by wind or rain splash (Simpson, 2021a). No specific data on dispersal distances of *P. minimum* is available (EPPO 2017b; EFSA *et al.*, 2020). Spread by urediniospores is assumed to mostly occur within a few hundred metres (EPPO, 2017b).

Means of human assisted spread identified are via tools, equipment, packaging, clothing, fruit and plants for planting (EPPO, 2017b; Buntain and Barry, 2019; Government of Western Australia, 2022).

Few of the recent introductions into new countries have an identified pathway (Anderson, 2022), but the international spread of *P. minimum* to new countries and continents has probably been due to trade of infected plants (EFSA *et al.*, 2020). In some countries and regions, the fungus was detected on recently traded *Vaccinium* plants, e.g. in Tasmania, Belgium and Sweden (EPPO 2016, 2022a; Parliament of Tasmania, 2018) and other findings have been reported from nurseries, e.g. Germany, Portugal and the United Kingdom (EPPO 2017a; Wichura *et al.*, 2020; Latham *et al.*, 2022).

PEST SIGNIFICANCE

Economic impact

Impact is mainly reported for *Vaccinium* hosts (EPPO, 2017b). Impact on blueberry appear to be more severe in warmer regions of the current range, but there are indications that damage is increasing in regions with a cooler climate where the fungus was not previously considered a problem (Hildebrand *et al.*, 2016; EPPO, 2017b).

In Canada, it is reported that severe outbreaks in lowbush blueberries (mainly *V. angustifolium*) can cause extensive defoliation in fields during the 'sprout' year. This has a negative impact on fruit bud development and can cause reduced yields the following year when berries are harvested (Hildebrand *et al.*, 2016; Agriculture and Agri-Food

Canada, 2021). In Michigan, the impact on yield is generally low but infection may cause premature defoliation (Miles *et al.*, 2020). The disease is more severe if *Tsuga* hosts are present in the vicinity (Miles *et al.*, 2020).

Outside its native range the fungus has mainly been reported to occur on *V. corymbosum* and its hybrids (EPPO, 2017b; EFSA *et al.*, 2020). In Australia, where damage appears to be highest, the disease is reported to cause losses of tens of millions of AUD every year in lost production and management costs (Simpson *et al.*, 2017). The fungus can also affect how blueberries are produced, e.g., organic blueberry growers in Tasmania had to apply fungicides to follow new requirement protocols (Parliament of Tasmania, 2018; Anderson, 2022).

Susceptibility varies between cultivars (Zheng *et al.*, 2017; Babiker *et al.*, 2018; Wichura *et al.*, 2020). In China, for example, leaf rust incidence was estimated to be 0, 3.5, 5.1 and 87.2% in different cultivars of *V. corymbosum* (Zheng *et al.*, 2017).

After discovering *P. minimum* in two nurseries in Germany, surveillance was conducted and a disease incidence of 19% was recorded (4 out of 21 sites inspected were found to be infected) (Wichura *et al.*, 2020). Infection was only found in old neglected *Vaccinium* plantings and on naturalized plants and infections levels were also low (Wichura *et al.*, 2020).

Control

A number of control measures are recommended in areas where the rust fungus causes disease in blueberry production sites.

It is recommended to use healthy planting material to avoid introducing infected plants into the production unit (Miles *et al.*, 2020; Simpson 2021a). In regions where the alternate *Tsuga* host is present it is recommended that they are removed from areas within 0.5 km from the production unit (Miles *et al.*, 2020; Agriculture and Agri-Food Canada, 2021), but this may not be feasible nor desirable (Schilder 2014). Susceptible cultivars should be avoided (Miles *et al.*, 2020) since cultivars of *V. corymbosum* differ greatly in susceptibility (Zheng *et al.*, 2017; Babiker *et al.*, 2018; Wichura *et al.*, 2020).

Reducing humidity within the plants by pruning to open the canopy (Buntain and Barry, 2019; Simpson, 2021a,b) and limiting overhead irrigation is also recommended (Miles *et al.*, 2020). Removal and disposal of fallen and pruned leaves are advised (Simpson, 2021b; Pscheidt and Ocamb, 2023). In nurseries in Germany, defoliation of diseased plants was found to be the most effective control measure used during a quarantine period and following this defoliation plants remained free of symptoms for at least 3 years (Wichura *et al.*, 2020).

Fungicides are used to control the disease (Hildebrand *et al.*, 2016; Buntain and Barry, 2019; Miles *et al.*, 2020). Several different fungicides are used in e.g. Australia and the USA (Buntain and Barry, 2019; Simpson, 2021a,b; Pscheidt and Ocamb, 2023). However, in Germany it was observed that the application of azole-based fungicides was not able to maintain plants free from the disease in nurseries when used as the only measure during a quarantine period (Wichura *et al.*, 2020) and Schrader *et al.* (2021) note that it has not been proven that fungicides have a curative effect.

For further details see e.g., Hildebrand *et al.*, 2016, Buntain and Barry 2019 and Simpson (2021a, b).

Phytosanitary risk

Following the discovery of the rust fungus in the EPPO region, Pest Risk Analyses have been performed for Germany (Schrader and Maier, 2015), Poland (Danielewicz *et al.*, 2016) and the EPPO region (EPPO, 2017b). The EPPO PRA concluded that the phytosanitary risk for the endangered area was moderate with a moderate uncertainty (EPPO, 2017b). Impact was expected on cultivated North American blueberries (EPPO, 2017b).

Pucciniastrum minimum occurs and causes disease in a wide range of climates (EPPO, 2017b). The fungus is found in climate types varying from tropical rainforest to a hemiboreal climate with the northern limit reaching 59°N (Anderson, 2022). Areas more at risk in the EPPO region were identified as i) areas with evergreen *Vaccinium* where *P. minimum* may overwinter and continue its infection cycles in the absence of *Tsuga*, ii) areas with extensive

cultivation of hosts in protected conditions, iii) areas with wet conditions during the vegetation season and iv) areas where plants of *Tsuga* are present, either in private gardens and parks or plantations (EPPO, 2017b).

The blueberry species *Vaccinium myrtillus*, which is native in the EPPO region, has been successfully inoculated in the laboratory (Latham *et al.*, 2021). It is currently not known if this plant species can be infected in the field, but the disease impact in the EPPO region would be higher if this was the case (EPPO 2017b).

Trade of plants for planting of *Vaccinium* has been identified as a high-risk pathway (EPPO, 2017b). EPPO recommends that *P. minimum* should be regulated as a quarantine pest by its member countries (EPPO, 2017c, 2022b).

PHYTOSANITARY MEASURES

Suggested phytosanitary measures to prevent the introduction of the fungus are described in the Pest Risk Analysis performed by EPPO (EPPO, 2017b). Measures are recommended for *Vaccinium* plants for planting, especially for *V. corymbosum* and its hybrids, *V. angustifolium* and *V. virgatum*. However, the host range is still uncertain. The plants should be free from the fungus, and this can be achieved by cultivating the plants in pest free areas or under physical isolation. Alternatively, a systems approach can be used by combining inspections, fungicide treatment, import of dormant plants free from leaves and plant debris. In addition, measures should be taken to prevent infection during transport. Other pathways for which measures may be considered are i) *Vaccinium* fruits, e.g., avoiding importation of large quantities fruit to be repacked at production units or handling waste to avoid spread of spores and ii) machinery, i.e. disinfecting machinery if used in *Vaccinium* production and moved between production units (EPPO, 2017b).

An EFSA pest survey card for *P. minimum* (as *Thekopsora minima*) is available to provide guidance for surveys for the fungus in the EU (EFSA *et al.*, 2020).

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