**Pistachio Rust-Pileolaria terebinthi**

*Pileolaria terebinthi* is an autoecious rust, completing all stages of its life cycle on trees in the genus *Pistacia*. It occurs on native species from the western Mediterranean to mainland China and northwestern India, but has not been reported from native species or the introduced pistachio tree in North America. Introduction to other pistachio-growing areas would likely happen through importation of infected trees or cuttings. No evidence exists that the commercially traded nuts could carry the pathogen from infected fruit. Locally the fungus is distributed by windborne basidiospores, aeciospores, urediniospores and fallen leaves bearing teliospores.

*Pileolaria terebinthi* Castagne

This rust fungus occurs in the pistachio-growing areas of Mediterranean Europe and northern Africa and in the range of wild *Pistacia* species from western Asia and northern India to China. Its range in China may or may not overlap with that of *P. Pistaciae*, another rust on *Pistacia*, that occurs in eastern Asia, including Japan, the Philippines, and Taiwan (USDA-SMML, 2009).

Beyond the Eurasian range of *P. terebinthi*, pistachio trees are grown in limited areas in a few countries, including Australia, Madagascar, Mauritius, Mexico, and California and New Mexico in the United States. California is now one of the major world producers of pistachio nuts (FAO, 2005), but the particular conditions that would favor the rust fungus on the few cultivars grown there may not occur or be frequent. The same questions of conditions and cultivars would also relate to the risk for other countries, though the potential economic impact might be less. Some wild *Pistacia* species are native to Mexico and the southwestern United States (USDA-ARS, 2009) and might also be susceptible to the rust.

Uredinia mostly hypophyllous, cinnamon-brown, erumpent in spots on leaves and fruits, broad, without peridium. Urediniospores subglobose to pyriform, yellowish-brown, pedicellate, verruculose, 24-44 x 16-25 um; walls 3-4 um, up to 6 um at apex. Pores 4, equatorial.

Telia mostly epiphyllous, erumpent in spots on leaves and petioles, sometimes confluent, 0.5-2 mm broad, dark brown. Teliospores globose- lenticular, horizontally compressed to disc-like shape when dry, deep reddish-brown, 25-32 x 20-25 um; walls 3-4 um; apical papillae low, lighter colored; pedicels hyaline, thick-walled, smooth, persistent, 100-260 um.


All stages of the life cycle occur on one host. Spermagonia and aecia have been observed in Greece (Griggoriou, 1992) and Iran (Hamzeh-Zarghani and Bani-Hashemi, 2002). In *Pileolaria*, spermagonia are flat and subcuticular, and the structures and spores of aecia resemble those of the uredinia (Hiratsuka et al., 1992).

The uredinial form of this rust was described by DeCandolle. In 1842, Castagne was the first to describe the telial form, thus he is the authority for the teleomorph name (USDA/SMML, 2009). A related species, *Pileolaria Pistaciae*, was not described from *Pistacia* until 1934 (Hiratsuka et al., 1992); as a result, some older Asian records and specimens of rust on *Pistacia* species may incorrectly identify the fungus found as *P. terebinthi*.

A related species, *Pileolaria pistaciae* Tai & Wei occurs in eastern Asia and the Philippines. Cummins (1937) observed that it differs from *P. terebinthi* in having more pointed and irregularly verrucose urediniospores with thinner walls and teliospores that are lighter in color with shorter pedicels. The key and descriptions of Teng (1996) distinguish *P. pistaciae* by its shorter, narrower and roughened pedicels.

*Alternaria* species can cause a leaf and fruit spot of *Pistacio vera*, with later development of dark masses of spores in the spots (Michailides, 2009). The chains of small, multicellular, brown conidia of *Alternaria* are easily distinguished from telia containing the single pedicellate reddish spores of *Pileolaria*.

**Detection and Inspection Methods** Cinnamon-brown uredinia appear on undersides of leaf spots and on fruits in spring and summer and dark mounded telia develop on the upper side of leaves in summer and autumn.

**Diagnostic Method**: One sequence of the ITS region of rDNA for this species is available in GenBank (NCBI, 2009); none is currently available for *P. pistaciae*.

**Notes on Habitat**: In a forest survey in Iran, severity of the rust on *Pistacio mutica* was found to decrease with plant age and elevation above 2000 meters. Female trees were more susceptible to the pathogen than males (Hamzeh-Zarghani and Bani-Hashemi, 2001).
Notes on Crops/Other Plants Affected: In a breeding nursery, Corazzza and Avanzato (1985) found that *Pistacia vera* was more severely attacked by rust than was *P. terebinthus*, while *P. atlantica* showed no symptoms of infection. Hamzeh-Zarghani and Bani-Hashemi (2001) report variation in severity depending on age and sex in *P. mutica*. *Pistacia chinensis* and *P. weinmannifolia* are reported as hosts for both species of rust, *Pileolaria terebinthi* and *P. pistaciae*, in China (Tai, 1979; Teng, 1996; Chen, 2002).

Symptoms-Description: Small orange-red to purple spots, often somewhat angular, and usually more visible on the lower side of the leaf, expand and may coalesce before becoming necrotic and dark brown. Uredinia develop in spots on leaves and on fruit clusters; infected fruit is malformed (Smith et al., 1988). With or without visible leaf spots, dark masses of teliospores develop in scattered or confluent pustules, primarily on the upper surface of leaves. Severe infection due to significant rain at the end of winter and beginning of spring can lead to defoliation (Assaweh, 1969).

Biological and Ecology: The stages of the life cycle have not been reported in detail, but are similar to those of other full-cycled rusts. Teliospores overwinter on fallen leaves on the forest floor (Hamzeh-Zarghani and Bani-Hashemi, 2006) and germinate in late winter or early spring, apparently after early-season rains. Telospore germination in vitro is stimulated by treatment with distilled water for two days at 15 C (Hamzeh-Zarghani and Bani-Hashemi, 2002). As in other rusts, the airborne basidiospores produced by teliospores will infect young leaves. Production of spermogonia and aecia is not commonly observed, but has been reported from Greece (Griggoriou, 1992) and Iran (Hamzeh-Zarghani and Bani-Hashemi, 2002, 2006). Spermogonia were found on *P. mutica* in late March (Hamzeh-Zarghani and Bani-Hashemi, 2006) and aeciospores and urediniospores were observed from April to June in western Iran (Hamzeh-Zarghani and Bani-Hashemi, 2002). Windblown aeciospores and urediniospores can spread the fungus to new parts of the plant or to other plants. Smith et al. (1988) report uredinia occurring in fruit clusters. However, little infection due to urediniospores occurred in the Fars region of Iran (Hamzeh-Zarghani and Bani-Hashemi, 2006). Free moisture in the form of rain or dew that is necessary for urediniospore germination may be absent later in the season. Telia develop in summer and autumn; in Iran (Hamzeh-Zarghani and Bani-Hashemi, 2002) and India (Bharat, 2005), teliospores could be collected in September.

Hamzeh-Zarghani and Bani-Hashemi (2002) report that the optimum temperature for aeciospore and urediniospore germination and germ tube growth was 25 C. The range of best germination was from 20 to 30 C, but germ tube growth was more sensitive, occurring at highest levels at 20 to 25 C. The optimum for teliospore germination and basidiospore differentiation was 20 C.

In northwestern India, teliospores were found to survive at significant levels to the next growing season on twigs and fruit on the tree, and in leaves and fruit on the ground, in an orchard of *P. vera*, the cultivated pistachio (Bharat, 2005). However, the fungus did not survive over winter as mycelium in infected twigs of the forest tree *P. mutica* in Iran (Hamzeh-Zarghani and Bani-Hashemi, 2006) and teliospores on leaves exposed to natural weathering on the forest floor lost germinability after one year (Hamzeh-Zarghani and Bani-Hashemi, 2002).

Natural dispersal: Sporidia (basidiospores), aeciospores and urediniospores of rusts are distributed by wind (Alexopoulos et al., 1996). Fallen leaves bearing teliospores could also be wind-dispersed.

Accidental Introduction: The teliospores can survive on detached leaves, fruits, and on twigs (Bharat, 2005), so that transport of these materials could be a means of introduction. Because pistachio trees are propagated primarily by grafting, asymptomatic rust-infected scions would be a particularly likely material to be transported deliberately.

Seedborne Aspects of Disease: Although teliospores from infected fruit might conceivably contaminate the harvested nuts, Richardson (1990) does not report this fungus as seedborne.

Economic impact: Losses up to 60% as a result of defoliation were reported from Egypt (Assaweh, 1969).

Prevention: *Species of Pileolaria* on pistachio are not specifically listed as pests of concern by the governments of Australia (DAFF, 2009) and the United States (Anon., 2008).

Cultural Control and Sanitary Measures: Although Bharat (2005) found that teliospores survived on fruits and twigs on pistachio trees in India, the results of his tests show that burying fallen leaves and fruit would prevent or reduce survival of teliospores, and thus reduce inoculum for the following season. Infected twigs might be removed by pruning.

Chemical Control: Chemical treatments are more likely to be applied for control of other fungal diseases of the shoots and leaves (see DAFF, 2006; Michailides, 2009). Fungicides should be evaluated for their efficacy against this rust (Smith et al., 1988).
Host resistance: Avanzato et al. (1987) observed different degrees of susceptibility among *P. vera* cultivars in a test nursery in Italy. Other species of *Pistacia* that might be sources of resistance, *P. terebinthus* and *P. atlantica*, were infected to a lesser extent than *P. vera*.

Gaps in Knowledge Research Needs: Additional information could be obtained on basic biology of infection and spread of the rust. Chemical treatments, sanitary measures and resistant varieties should be evaluated as means of control.

References


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