Coleosporium Rusts

Angelica Werth

November 26, 2019

Principles of Plant Pathology/PLPA 3100

for Sustainable Landscape Demonstration Garden

HORT4080_007 CI# 827 posting

Introduction

Rust fungi are a group of fungal plant pathogens with a rather complex life cycle that fall into the category of Basidiomycetes, the most advanced group of plant pathogenic fungi. Rusts are typically very visible in the summer in their urediniospore stage because the urediniospores are produced in large pustules that have a yellow, orange, or reddish "rusty" color; this coloration is what gives the disease its name. There are a number of genera of rust fungi, many of which have been studied extensively, but one of interest to growers of ornamentals is *Coleosporium.*

Pathogen

Coleosporium rusts are heteroecious and macrocyclic (UC IPM 2019). The term "heteroecious" means that they require two separate hosts, often belonging to different families of plants, to complete their life cycle. The descriptor "macrocyclic" refers to the fact that this genus of fungi produces all five spore types possible to a rust fungus: basidiospores, pycniospores, aeciospores, urediniospores, and teliospores (Figure 1). *Coleosporium* is also polycyclic, meaning that the fungus can infect the same host repeatedly, or more than one host, in a single growing season. In the case of rust fungi, this is made possible by the urediniospore stage (also called the repeating stage) because the spores are produced continually throughout the summer, allowing up to 15 disease cycles in a single summer in the case of *Coleosporium* (Chapell and Rausher 2016). As with all rust fungi, *Coleosporium* is obligately parasitic (Arthur 1934), so it cannot survive for long without a host. The disease is commonly referred to either by the genus or the host plant name, followed by the word "rust"; for example, "*Coleosporium* rust" or "Frangipani rust". The pathogen belongs to the order Pucciniales, the family Melampsoraceae, and the tribe Cronartiease (Arthur 1934). The hyphae of the fungus are branched and septate, and they produce haustoria for feeding (Kolmer and Groth 2009). To distinguish between species, three key features may be used: the color of the pycnia, the arrangement, size, and shape of the aecia, and the aecial host plant, which is the host that houses the pycnia and aecia (Hedgcock 1928). Pycnia are the structure on the upper side of leaves of the aecial host that produce pycniospores, and range in color from yellow to orange to red to brown to black, darkening as they mature (Hedgcock 1928). Aecia are structures on the underside of leaves of the aecial host and that produce aeciospores; these appear a month or two later than the pycnia (Figure 2; Hedgcock 1928). These spores are oblong to round in shape with verrucose spore walls (Weir 1925; Arthur 1934). Later in the disease cycle, the urediniospores develop in pustules beneath the epidermis of the telial host plant, then eventually rupture it. These spores are globose to oblong and appear yellow or orange and powdery; they are formed in short chains with intercalary cells. The cell walls of urediniospores are glassy or transluscent in appearance, while the spore walls are warty. Telia look like yellow or orange wax-like sori, and are often flat and dense; they are composed of teliospores, which are this fungus's survival structure (Weir 1925). In the spring, the teliospores germinate and form a phragmobasidium, composed of four cells, which produces the basidiospores that infect the aecial host (Arthur 1934).

Host Plants

This complex life cycle occurs on two different hosts: the aecial host and the telial host. The aecial hosts is where the development of pycnia and aecia occur, while the telial hosts house the uredinia, telia, and basidia (Arthur 1934). Interestingly, *Coleosporium* has been documented to have a significant number of telial hosts, but only one known genus of aecial hosts: *Pinus* (Hedgcock 1928). In the southeastern United States, the most important aecial host is *Pinus taeda*, also known as loblolly pine (Chapell and Rausher 2016). Telial hosts are typically herbaceaous dicots in temperate regions, but may also include monocots and woody dicots in tropical regions (Arthur 1934). The Convulvulaceae and Caruaceae families both include a number of telial hosts; a couple more specific examples of note are *Amsonia*, *Plumeria*, aster, and morning glories (Table 1; Abbasi et al. 2016; Arthur 1934; Hedgcock 1928).

Symptoms and Signs

Symptoms of this disease include chlorosis on leaves, dieback, leaf spotting, and defoliation (Hedgcock 1928; Abbasi et al. 2016; McMillan 1984). Leaf drop may be the most problematic for growers, since it results in plants which may be impossible or more difficult to sell. If the plant is infected early in the season, leaves may turn brown and fall off as early as two months into the spring. Chlorotic spots may be seen on the upper surface of leaves, which often corresponds to the uredinia on the undersides of the leaves (Nelson 2009). These characteristic powdery pustules full of yellow-orange urediniospores on the undersides of leaves are often the most obvious indication that a plant is suffering from a *Coleosporium* rust (Figure 3; McMillan 1984). However, other spores, such as aeciospores, may also be visible, especially with magnification, and are often found on chlorotic spots on the leaves (Figure 3; Hedgcock 1928).

Disease Cycle and Development

The disease cycle of *Coleosporium*, as previously mentioned, involves five spore types and two hosts. The aecial host (*Pinus)* is infected by the primary inoculum, basidiospores, in the early spring, which develop pycnia, and then aecia (UC IPM 2019). The aeciospores then infect telial hosts, often carried on the wind or simply by falling on them from the aecial hosts; remember that aecial hosts are pine trees, while telial hosts are often smaller herbaceous dicots that often grow beneath these trees (Chapell and Rausher 2016). The telial hosts develop uredinia in the summer, which may infect multiple hosts or the same host repeatedly, making

Coleosporium rust a polycyclic disease (Chapell and Rausher 2016). Urediniospores are followed by telia in the fall then basidia (Chapell and Rausher 2016). The urediniospore stage is deserving of further examination, because this is when a significant amount of spread occurs. Urediniospores, the secondary inoculum in this disease cycle, are carried on the wind (Nelson 2009). Interestingly, some urediniospores of a single species of *Coleosporium* are able to infect a host plant from a different genus (but the same family) from the host plant on which it was produced; this has been observed on *Aster* and *Solidago* (Weir 1925). The sheer number of urediniospores produced and the number of plants that can be infected in this stage are largely responsible for *Coleosporium*'s success as a pathogen.

History and Distribution

Coleosporium spp. has been observed on almost every continent: North and South America, Asia, islands in the Pacific, Africa and Europe (McMillan 1984; Kolmer and Groth 2009). In the United States, *Coleosporium* has been observed in almost every state (Table 1; Arthur 1934). What is interesting is that some species have only been found in a very small area, such as a single county, while others have been found in over half the states and several other countries. An example of the latter is *C. vernonieae*, which has been found in at least 28 states as well as the West Indies and South America (Arthur 1934). Studies have been done on the spread of *C. plumeriae* because it has particular economic significance. One such study showed that the pathogen began to spread rapidly in the 1980s from Central America to Pacific countries, Asia, and Africa (Kakishima et al. 2017). The study suggests that the long-distance spread was due to weather events such as a typhoon, El Niño and La Niña, as well as people moving plants (Kakishima et al. 2017). In another fascinating study on *C. ipomoeae* and morning glories, researchers found that one genotype will often only infect one species when tested on plants in the local community, but will often infect two or three different hosts when tested on plants from non-local communities (Chapell and Rausher 2016). This study has implications on our understanding of the distribution of the disease, as well as host plant resistance.

Importance/Significance

The *Coleosporium* rusts with the most economic impact are those which impact ornamentals grown in gardens or commercially, such as *C. ipomoeae* and *C. plumeriae* (McMillan 1984; Chapell and Rausher 2016). Perhaps the most important example is Plumeria rust (*C. plumeriae*), which is a problem in Hawaii, where *Plumeria* is an important crop. The average annual sales in Hawaii over 2000-2005 was $505,000 (Nelson 2009). This number declined from $506,000 in 2005 to $285,000 in 2009, and while the ornamental plant business in general experienced in Hawaii during this period was also certainly a factor, the difficulty of managing this disease most likely was also a factor (USDA Hawaii 2011). In other places, the fungus may occasionally cause an infection severe enough to damage the aecial host, pine trees; *C. asterum* is particularly noted for this. This is typically a problem in pine nurseries and Christmas tree plantations; however it is rarely a problem for more than one year in a row (UC IPM 2019).

Management Strategies

Three key strategies have been identified to aid in the management of *Coleosporium* rusts: environmental manipulation, fungicides, and biological controls. It has been noted that this fungus tends to cause the most damage in years with abundant rainfall occurring at the same time as new growth, in the spring (UC IPM 2019). Thus, the most important recommendation in terms of growing conditions is to minimize or reduce humidity (McMillan 1984). This can be achieved through proper spacing of plants and air circulation. In greenhouses, not allowing water to puddle on the floor through proper watering practices and well-placed floor drains is also useful. Fungicides may be applied as a foliar spray in the spring, when the infection is taking hold (McMillan 1984). A systemic fungicide called oxycarboxin, found in a product called Plantvax, which belongs to the MOA group C and has a FRAC code of 7, has been shown to be effective in reducing Plumeria rust, using number of uredinial pustules and amount of defoliation as the standard, especially in a nursery setting (Fungicide Resistance Action Committee 2019; McMillan 1984). It is recommended to use fungicides as part of an integrated pest management approach, or at the least to rotate them, because fungi can develop resistance to a specific class of fungicides or mode of action. Protectant products may also be applied before infection is seen; such products include chlorothalonil, mancozeb, and sulfur, as well as products containing copper (Jackson 2017). Some research has also been done into the use of biological controls for management of *Coleosporium* rusts, especially on *Plumeria*. A predatory midge has been found to reduce the amount of Plumeria rust (Nelson 2009). Additionally, a fungus called *Verticillium lecanii* may be used for the control of insects and some rusts, including *Coleosporium*. In one study, in which conidia of the fungus were sprayed on the foliage of *Plumeria*, visible pustules and defoliation caused by *Coleosporium* rust were significantly decreased, especially in a greenhouse setting (McMillan 1985).

Summary and Conclusions

Coleosporium rusts are a group of plant pathogenic fungi with a complex life cycle consisting of five spore types and two hosts. This disease causes symptoms including leaf spot, chlorosis on leaf spots, dieback, and defoliation, but the defining characteristic are the yellow-orange uredinia on the undersides of leaves. The fungi primarily damage their telial hosts, which are often ornamentals, including aster, morning glories, and *Plumeria*. Economic impacts are often related to heavy infections in *Plumeria* or pine tree nurseries. The genus has a widespread geographic range, including every continent except Antarctica and Australia. Key management strategies include environmental manipulation, fungicides, and biological controls. The study of this interesting disease is important in deepening our understanding of rust fungi in general, in addition to having important implications for growers whose plants are suffering the effects of this disease.

Supplementary Materials

Figure 1: Rust life cycle (Kolmer and Groth 2009)

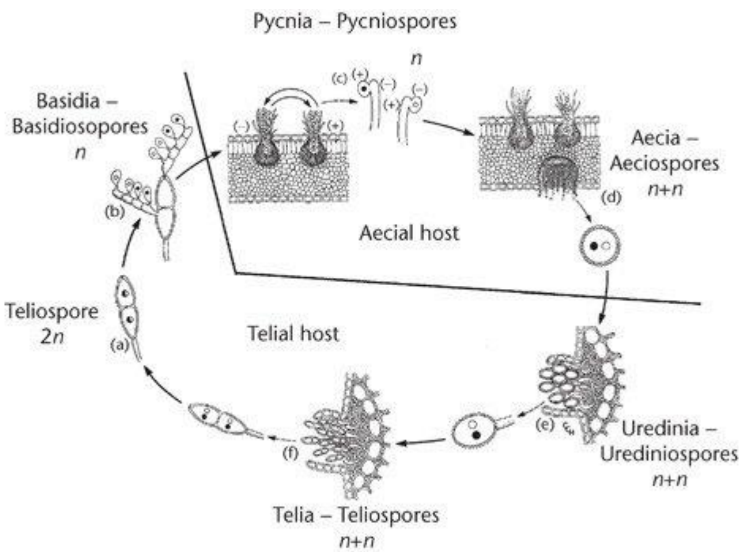

Figure 2: Aeciospores (Weir 1925)

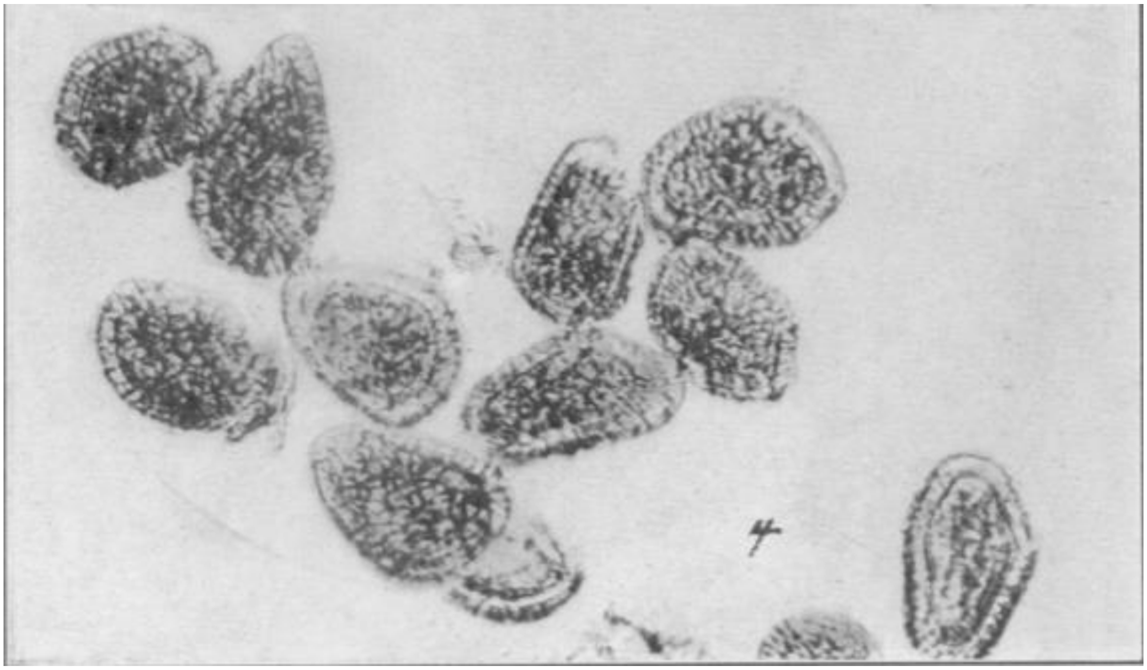

Figure 3: *Coleosporium* urediniospores on Plumeria leaf (Nelson 2009)

Table 1: Telial hosts and locations of selected species of *Coleosporium* (Arthur 1934)

Species	**Telial Host(s)**	**Locations Include…**
C. jonesii	Grossularaceae	AZ, CA, CO, ID, MN, MT, NM, NE, SD, UT, WI, WY
C. minutum	*Forestiera ligustrina*	Central Florida
C. apocynaceum	*Amsonia tabernaemontana, A. ciliata*	AL, FL, GA, SC

C. ipomoeae	Convolvulaceae	AL, AR, AZ, DC, DE, FL, GA, IL, IN, KS, KY, LA, MD, MI, MO, MS, NC, NJ, OH, OK, PA, SC, TN, TX, VA, WV, Mexico, Central America, West Indies, South America
C. viburni	*Viburnum* spp.	IA, MI, WI, Canada, Central America, Japan, Mexico, and South America
C. campanulae	Campanulaceae and *Lysimachia quadrifolia*	CA, CT, IL, IN, KY, MD, MI, MO, MS, NH, NJ, NY, OH, PA, TN, VT, WI, WV, Europe and Japan
C. vernoniae	*Vernonia* spp.	AL, AR, CT, DC, DE, GA, FL, IA, IL, IN, KY, KS, LA, MA, MD, MO, MS, NC, NJ, NE, OH, OK, PA, SC, TN, TX, VA, WV, South America and the West Indies
C. elephantopodis	*Elephantopus* spp.	AL, AR, DC, DE, FL, GA, IL, IN, KY, LA, MD, MI, MO, NC, NJ, OH, OK, PA, SC, TN, TX, VA
C. aridum	*Brickellia californica*	CA in the Mojave Desert
C. laciniariae	*Liatris* spp.	AL, AR, FL, GA, NJ, TN
C. solidaginis	Carduaceae (includes 50+ species of aster)	AK, CA, CO, CT, IA, IN, FL, MA, MD, ME, MI, MN, ND, NE, NH, NJ, NY, PA, SC, TX, VT, WV, Canada, China, Mexico, and Japan
C. delicatulum	*Euthamia* spp.	CT, DC, DE, FL, IN, KS, LA, MA, MD, ME, MO, NH, NJ, NY, PA, RI, TX, VA, VT, WV
C. adenocaulonis	*Adenocaulon bicolor*	Corvallia, OR
C. madiae	Carduacaeae	CA, OR, WA, western Canada
C. inconspicuum	*Coreopsis* spp. (tickseed)	DC, MD, OH, GA, NC, SC, TN, VA
C. helianthi	*Helianthus* spp.	AL, AR, DC, GA, IN, IL, MD, MI, MO, NC, NY, OH, OK, PA, SC, TN, VA, WI, WV
C. terebinthinaceae	Carduaceae	AL, AR, GA, IA, IL, IN, KS, LA, MI, MO, NC, PA, SC, TN, TX, VA
C. occidentale	*Senecio* spp.	CA, OR, UT, WA, WY
C. senecionis	*Senecio vulgaris*	CO, RI, Europe, Japan, Siberia, South America
C. sonchi-arvensis	*Sonchus asper*	WI, Europe, West Indies

References

Abbasi, M., Aime, M. C., Creswell, T. C., and Ruhl, G. E. 2016. First report of rust disease caused by *Coleosporium apocynaceum* on Amsonia 'Blue Ice' in Indiana. Plant Disease 100: 1786.

Arthur, J. C. 1934. Manual of the Rusts in United States and Canada. Purdue Research Foundation, Lafayette, IN.

Chapell, T. M., and Rausher, M. D. 2016. Evolution of host range in *Coleosporium ipomoeae*, a plant pathogen with multiple hosts. Proceedings of the National Academy of Sciences of the United States of America 113:5346-5351.

Fungicide Resistance Action Committee. 2019. Fungal control agents sorted by cross resistance pattern and mode of action. Retrieved 28 November 2019 from: https://www.frac.info/docs/default-source/publications/frac-code-list/frac-code-list-2019.pdf.

Hedgcock, G. 1928. A key to the known aecial forms of *Coleosporium* occurring in the United States and a list of the host species. Mycologia 20:97-100.

Jackson, G. 2017. Frangipani rust. Pacific Pests and Pathogens. Retrieved 14 December 2019 from http://www.pestnet.org/fact_sheets/frangipani_rust_243.htm.

Kakishima, M., Ji, J. X., Zhao, P., Wang, Q., Li, Y., and McKenzie, E. H. C. 2017. Geographic expansion of a rust fungus on *Plumeria* in Pacific and Asian countries. New Zealand Journal of Botany 55:178-186.

Kolmer, J. A., Ordonez, M. E., and, Groth, J. V.2009. The rust fungi. In: Encyclopedia of Life Sciences (ELS). John Wiley & Sons, Ltd, Chicheste, U.K.
DOI: 10.1002/9780470015902.a0021264

McMillan, R. T., Jr. 1984. Oxycarboxin a new fungicide for control of frangipani rust in nursery and field. Proceedings of the Florida State Horticultural Society 97:247-248.

McMillan, R. T., Jr. 1985. Biological control of frangipani rust with *Verticillium lecanii*. Proceedings of the Florida State Horticultural Society 98:328-329.

Nelson, S. 2009. *Plumeria* rust. Cooperative Extension Service Publication no. PD-61. College of Tropical Agriculture and Human Resources. University of Hawai'i at Manoa.

UC IPM. 2019. Pests in gardens and landscapes: Pine Rusts—Various fungi. Agriculture and Natural Resources, University of California. Retrieved 20 October 2019 from: http://ipm.ucanr.edu/PMG/GARDEN/PLANTS/DISEASES/pinerust.html

USDA Hawaii. 2011. Statistics of Hawaii agriculture 2009. Retrieved 28 November 2019 from:https://www.nass.usda.gov/Statistics_by_State/Hawaii/Publications/Annual_Statistical_Bulletin/2009/2009.pdf.

Weir, J. 1925. The genus *Coleosporium* in the northwestern United States. Mycologia 17: 225-239.