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GYMNOSPORANGIUM RUSTS: COMMON CEDAR RUST DISEASES IN CONNECTICUT

Although there are over 40 species of Gymnosporangium rusts in North America, three species are significant throughout Connecticut and New England. These are Cedar-Apple Rust (*Gymnosporangium juniperi-virginianae)*, Cedar-Hawthorn Rust (*Gymnosporangium globosum*), and Cedar-Quince Rust (*Gymnosporangium clavipes*). These rust fungi are heteroecious, meaning that they require two different hosts to complete their life cycles. The primary hosts are members of the Rosaceae. On these hosts, infections appear as colorful spots on leaves, which is often followed by premature leaf drop. Swellings of midveins, petioles, and twigs, and distortion or dieback of infected twigs can also occur. Fruit can sometimes be distorted. The alternate hosts are evergreens in the genus *Juniperus*. Symptoms on these hosts appear as galls, swellings, witches'-brooms, and twig and branch dieback. These fungi are indigenous and widespread throughout the Northeast, especially in areas where both hosts grow in close proximity.

In 2009, a non-native Gymnosporangium rust, Japanese Apple Rust, *Gymnosporangium yamadae*, was detected on apple and crabapple in Connecticut, as well as Maryland, New Jersey, New York, and Pennsylvania. It is thought that this pathogen has probably gone undetected for many years because it may have been confused with Cedar-Hawthorn Rust, which has very similar symptoms.

CEDAR-APPLE RUST

Cedar-apple rust is caused by the fungus *Gymnosporangium juniperi-virginianae*. The primary hosts are species of *Malus*--apple (*M. domestica*) and crabapple (*M. sylvestris* and other *Malus* species). The alternate hosts are members of the genus *Juniperus*, which includes the native Eastern red cedar (*J. virginiana*) as well as many ornamental junipers (e.g., Chinese, low, and creeping junipers).

The symptoms of cedar-apple rust disease on Eastern red cedar and other junipers are inconspicuous during the winter and appear as brown, kidney-shaped galls that vary in size from ¼-2 inches in diameter (Figure 1). As the temperatures begin to rise in the spring, the fungus begins to grow in the galls (Figure 2). After these conditions, spectacular and distinctive bright orange, gelatinous telial (spore) horns develop and protrude from the surface of these galls (Figure 3). Telia can be up to four inches long. Heavily infected junipers appear to be "decorated" with many colorful galls

Figure 1. Dormant cedar-apple rust gall overwintering on Eastern red cedar.

Figure 2. Gall with telial horns beginning to emerge in early to mid-spring.

Figure 3. Spectacular, gelatinous telial horns develop from galls after rain.

(Figure 4). Galls can result in dieback of twigs.

Figure 4. Eastern red cedar "decorated" with many galls in spring.

Spores called teliospores are produced in the gelatinous spore horns or tendrils. When the teliospores germinate, they produce another type of tiny spore called a basidiospore. These spores can only infect apple and crabapple. Basidiospores are released and carried by wind and driving rain to newly emerging leaves of the alternate hosts, apple and crabapple. As many as 7.5 million basidiospores may be produced in a single gall. These spores have been shown to be carried as far as six miles, but most infections occur within several hundred feet from the source. Once the spores land on the emerging apple or crabapple leaves, they germinate and infect the leaves when they are wet.

Symptoms of infection on the apple and crabapple hosts are also quite colorful. Lesions first appear in early June as greenish-yellow spots that increase in size.

Figure 5. Symptoms of cedar-apple rust on red-pigmented crabapple (upper leaf surface).

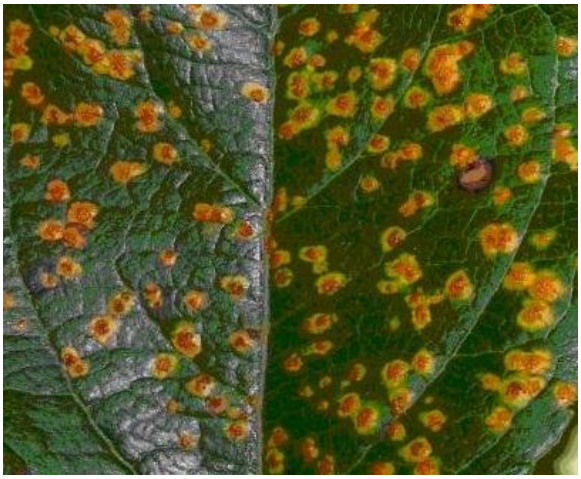

Figure 6. Symptoms on the upper surface of an apple leaf.

Figure 7. Close-up of rust lesion.

They develop into characteristically brightly colored spots--the color can vary from yellowish-orange to red, depending upon the apple or crabapple cultivar (Figures 5, 6, and 7). Symptoms are visible on both the upper and lower leaf surfaces.

Symptoms can develop on fruit and rarely on twigs. By midsummer, minute aecia about $^{1}/_{8}$ inch long (also called "spore cups") develop at the edge of the lesions on the lower leaf surfaces (Figures 8 and 9).

Figure 8. Aecia present in the rust lesion on the lower leaf surface.

Figure 9. Close-up of short, cylindrical aecia.

The spores produced in these cups are called aeciospores. These one-celled spores are released from midsummer into autumn.

Aeciospores can only infect junipers and cannot infect other apples or crabapples. These spores are dry and are carried by wind back to the juniper and red cedar hosts. When the spores land, they germinate and stimulate the formation of galls. Galls are initially green to greenish-brown and gradually darken to brown and enlarge as they age. This initiates another cycle of disease. It takes from 19-22 months to complete one life cycle of this fungus.

CEDAR-HAWTHORN RUST

Cedar-hawthorn rust is caused by *Gymnosporangium globosum* and is very similar to cedar-apple rust. However, its primary host range is larger than for cedar-apple rust. The most common hosts are apple, crabapple, and *Crataegus* (hawthorn). Occasional hosts include *Amelanchier* (serviceberry), *Cydonia* (quince), *Pyrus* (pear), and *Sorbus* (mountain ash). The alternate hosts are in the genus *Juniperus*, which includes the native Eastern red cedar (*J. virginiana*) as well as many ornamental junipers (e.g., Chinese, low, creeping, and savin junipers).

Symptoms of cedar-hawthorn rust disease on Eastern red cedar and other junipers are often inconspicuous, especially during winter. They are small brown galls from $^{1}/_{8}$-$^{9}/_{16}$ inch in diameter (Figure 10), and can appear flattened on the side attached to the twig. As the temperatures rise in the spring, the fungus begins to grow in the galls. After periods of moisture, bright orange, gelatinous spore horns protrude from the surface of the galls (Figures 11 and 12). They are typically much smaller and less spectacular than those produced in cedar-apple rust and rarely cause twig dieback.

Teliospores are produced in the spore horns. They germinate and produce tiny basidiospores (Figures 13 and 14).

Figure 10. Dormant cedar-hawthorn gall on juniper.

Figure 11. Small telial horns protruding from a small gall on the stem.

Figure 12. Cedar-hawthorn galls in spring.

Basidiospores are released and carried by wind and driving rain to newly emerging

leaves of the alternate hosts, apples, crabapples, hawthorns, and others. Millions of basidiospores are carried distances as far as fourteen miles, but most infections occur within several hundred feet from the source. Cedar-hawthorn rust galls often produce spores for more than one year, unlike the cedar-apple rust galls, which only produce spores for one season.

Once the basidiospores land on emerging apple or crabapple leaves, they germinate and infect the leaves when they are wet.

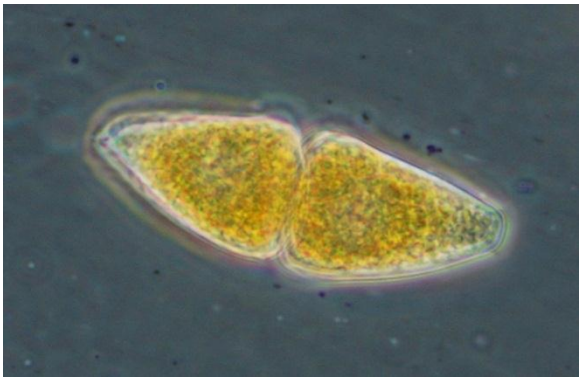

Figure 13. Two–celled teliospore of cedar-hawthorn rust.

Figure 14. Germinating teliospore produces basidia from which tiny basidiospores are formed.

Infections of the rosaceous hosts commonly occur on leaves. However, infections can also occur on fruit, petioles, and twigs. On leaves, rust lesions first appear in early June as greenish-yellow spots that increase in size. They develop into characteristically brightly colored spots--the color can vary from yellowish-orange to red, depending upon the host species and cultivar (Figure 15). Symptoms are visible on both the upper and lower leaf surfaces. By midsummer, aecia are visible on the lower surface of mature leaf lesions as well as on infected fruit, petioles, and twigs. They appear as long tubes, up to ½ inch long (Figure 16), which are distinctly different than the short aecia of cedar-apple rust.

Figure 15. Brightly colored cedar-hawthorn rust lesions.

Figure 16. Aecia protruding from the lower surface of a cedar-hawthorn rust lesion.

Lesions also develop in fruit (Figure 17). Aeciospores are single-celled spores produced in the aecia (Figures 18 and 19).

Figure 17. Young apple fruit with cedar-hawthorn rust lesions.

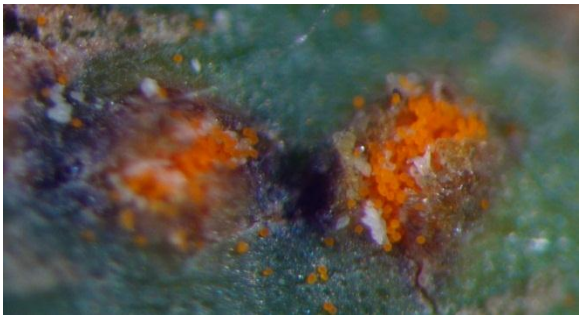

Figure 18. Close-up of aecia with aeciospores breaking through developing fruit.

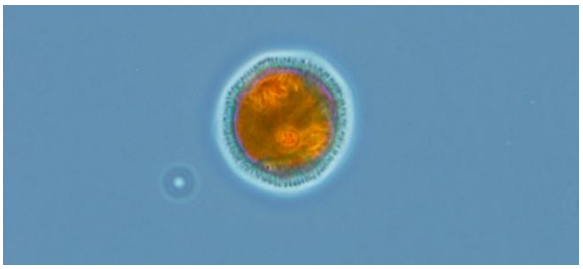

Figure 19. Photomicrograph of an aeciospore of the cedar-hawthorn rust fungus.

These spores are released from midsummer into autumn and infect junipers; they cannot infect other rosaceous hosts. Aeciospores are released anytime during rain or in early morning, in the absence of precipitation. Once on the juniper hosts, they germinate and stimulate the formation of galls, thereby initiating another cycle of disease. Small galls form that are initially green to greenish-brown and gradually darken to brown as they age. It takes approximately 24 months to complete one life cycle of this fungus.

CEDAR-QUINCE RUST

Cedar-quince rust, caused by the fungus *Gymnosporangium clavipes*, is very similar to cedar-hawthorn rust. However, the range of primary, rosaceous hosts is even broader than that of cedar-hawthorn rust and covers over 480 species in 11 different genera. The list includes apple, crabapple, hawthorn, serviceberry, and mountain ash, as well as Aronia (chokeberry), *Chaenomeles* (flowering quince), and *Cotoneaster*. Apples are fairly resistant, although when fruit are infected, they are distorted. The alternate hosts are in the genus *Juniperus*, which includes the native Eastern red cedar (*J. virginiana*) as well as many ornamental junipers (e.g., common, creeping, and savin junipers).

Symptoms of cedar-quince rust disease on Eastern red cedar and other juniper hosts are different than the previously described rusts. Rather than forming galls, infections result in mild swellings of the twigs. Sections of bark in these areas also become flaky. Many twigs die during the first year of infection. The ones that survive become perennial, gradually enlarge, and become spindle-shaped. Telia form each year in these swellings as the temperatures begin to rise in the spring. They first appear as orange, cushion-like masses in cracks in the bark (Figures 20 and 21). After rainfall, the telia gelatinize and become gooey masses that seem to ooze out of cracks in the bark (Figure 22). Telia can be produced in infected twigs for as long as 20 years. Teliospores, formed in the telial masses,

germinate and form tiny basidiospores. Basidiospores are released into the air and blown to the rosaceous hosts. The timing of basidiospore development and release is usually synchronized with bud break of the rosaceous hosts. Eastern red cedars that have been infected with high levels of this rust for many years gradually lose vigor, thin, and decline.

Figure 20. Swellings on juniper with orange telia prior to gelatinization.

Figure 21. Close-up of telia on swollen, spindle-shaped branch.

Figure 22. Gelatinous telial mass oozing out of small branch swelling.

Basidiospores of cedar-quince rust infect leaves, petioles, thorns, young branches, and fruit of rosaceous hosts. On leaves, typical rust lesions (see Figures 6 and 15) can occur, but are not as common as other types of symptoms, which include swelling of midveins or petioles (Figure 23).

Figure 23. Cedar-quince infection of the midvein of a hawthorn leaf results in curling of the leaf.

In addition to leaf infections, this fungus infects and sporulates in developing, green shoots (Figures 24 and 25).

Figure 24. Infection of green *Amelanchier* shoot by the cedar-quince rust fungus.

Figure 25. Close-up of aecia on infected *Amelanchier* shoot.

Shoot and thorn infections can develop, especially on susceptible cultivars of hawthorn. They appear as swollen, spindle-shaped cankers that distort the growth. The fungus can overwinter in the margins of these tissues. In summer, white, tubular aecia form and produce bright orange aeciospores in these structures (Figures 26, 27, and 28).

Figure 26. Shoot and thorn of *Crataegus* infected with cedar-quince rust fungus.

Figure 27. Close-up of white, tubular aecia on infected *Crataegus* thorn.

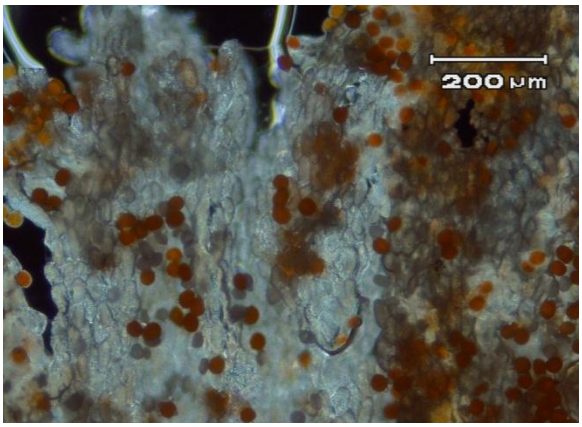

Figure 28. Photomicrograph of bright orange aeciospores present in white aecial tissues.

Fruit of *Amelanchier* and *Crataegus* are commonly infected. However, they are only believed to be susceptible for a short period when they are young. Many white, tubular aecia form on the fruit and the fruit subsequently die (Figures 29 and 30).

Figure 29. Infected *Amelanchier* fruit covered with white, tubular aecia.

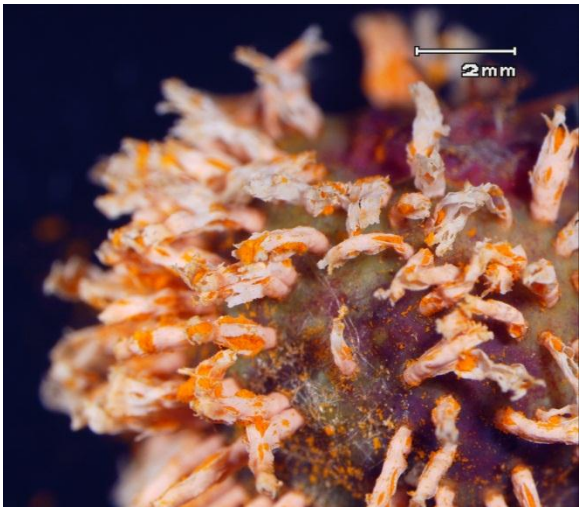

Figure 30. Close-up of aecia containing bright orange aeciospores.

Aeciospores are released from infected rosaceous hosts in response to rain or when aecial drying occurs in response to lower levels of relative humidity. This occurs from midsummer into autumn. Aeciospores infect needles and green tissues of junipers; they cannot infect other rosaceous hosts. Once on the juniper hosts, they germinate and infect the tissues, which remain asymptomatic until the following spring. These infections initiate another cycle of disease. It is still uncertain as to whether the life cycle of cedar-quince rust takes one or two years.

Cedar-quince rust is the most damaging on its rosaceous hosts of the three Gymnosporangium rusts discussed in this fact sheet. This is associated with several factors, including the broad host range and the tissues that it infects—fruit, petioles, and green stems, and the resulting distortion and dieback of stems.

JAPANESE APPLE RUST

Japanese Apple Rust is a non-native Gymnosporangium rust caused by the fungus *Gymnosporangium yamadae*. It was identified in Connecticut in 2009. Rosaceous hosts include *Malus* species such as *M. domestica* (cultivated apple), *M. baccata*, and *M. toringo*. Juniper hosts include *Juniperus chinensis* (Chinese juniper), *J. chinensis var. procumbens* (dwarf Chinese juniper), *J. chinensis var. sargentii* (Sargent juniper), and *J. squamata*. Concern about this new pathogen is focused on how existing cultivars of apple and crabapple that have been bred for resistance to native Gymnosporangium species will react to this non-native species of rust.

A table of the key features of the three common rusts is found at the end of this fact sheet.

DISEASE MANAGEMENT:

Gymnosporangium rust diseases are generally not considered life-threatening to either juniper or rosaceous hosts, though repeated, defoliation can weaken trees and

predispose them to winter injury, insects, and opportunistic pathogens. Therefore, these diseases are usually effectively managed through the combined use of culture, sanitation, and resistance. However, with recurrent, significant, defoliation, twig dieback, or fruit loss on rosaceous hosts, fungicide sprays may be necessary.

1. Culture

Involves removal of either host within ½-1 mile from the other, although in most cases this is not a feasible option.

2. Sanitation

Involves pruning and removing galls from the red cedar and juniper hosts during the dormant season. Once again, this is practical in limited situations: where only a few trees are involved and only a few galls are present.

3. Resistance

Involves selection and planting of resistant cultivars or varieties. This can be an effective method for managing these diseases, since this reduces the level of disease that develops. Resistance to cedar-apple and cedar-hawthorn rusts is most common. At present, there is very limited available information about resistance to cedar-quince rust. Some juniper species and cultivars and some rosaceous species and cultivars have been identified to have varying levels of resistance to rust diseases.

Examples of resistant rosaceous hosts:
Apple cultivars: Include 'Delicious,' 'Empire,' 'Jonamac,' 'Liberty,' 'Macfree,' 'Redfree,' and 'Novamac.'
Crabapple cultivars: Include 'Ellwangerina,' 'Henry Kohankie,' 'Ormiston Roy,' 'Snowdrift,' 'Zumi,' 'Red Jewel,' and 'Red Baron.'
Hawthorn species and cultivars: *Crataegus crus-gall, C. intricate, C. laevigata* 'Autumn Glory,' *C. phaenopyrum,* and *C. viridis* 'Winter King.'
Examples of Juniper hosts with resistance: Include *Juniperus virginiana* 'Aurea,' 'Skyrocket,' 'Tripartita;' *J. communis* 'Aureospica,' 'Aurea,' 'Depressa;' *J. horizontalis* 'Argenteus,' 'Douglasii,' 'Plumosa;' *J. sabina* var. *tamariscifolia*, *J. sabina* 'Broadmoor,' 'Fastigiata;' *J. squamata* 'Meyeri.'

4. Fungicides

The final strategy for disease management involves proper selection, timing, and application of fungicide sprays, especially for high-value, susceptible plants. Thorough coverage of all parts of the tree is necessary and the sprays should be applied until run-off. The fungicide label has information on plant hosts, dosage rates, and safety precautions. Among the fungicides registered for management of Gymnosproangium rusts in Connecticut are azoxystrobin, chlorothalonil, mancozeb, triadimefon, propiconazole, and myclobutanil. Sulfur is an organic management option. Applications will suppress, but not control these diseases. Biological pesticides have not been demonstrated to have significant efficacy.

If harvesting apple or crabapple fruit for consumption, please consult the fact sheet *Disease Control for Home Apple Orchards*. This guide contains information on fungicides registered for use on edible fruit. The fungicide label has information on plant hosts, dosage rates, and safety precautions.

Use of fungicides to protect *Juniperus* species has yielded disappointing results due to the difficulty in determining the timing of the applications—long, midsummer through fall infection periods for these rusts remain poorly understood. One of the only fungicides registered for use for rust control on junipers in the landscape is triadimefon.

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Key Features of Common Gymnosporangium Rust Diseases

	Cedar-Apple Rust	Cedar-Hawthorn Rust	Cedar-Quince Rust
Deciduous (Rosaceous) Hosts	Apple and crabapple.	Hawthorn, apple, crabapple; sometimes pear, quince, and serviceberry.	Most commonly infected are hawthorn, crabapple, quince, flowering quince, apple, serviceberry, mountain ash, chokeberry, and cotoneaster.
Affected Plant Parts	Mainly leaves; some fruit infections can occur.	Mainly leaves; occasionally petioles, fruit, and stems.	Mainly thorns, new twigs and fruit; occasionally petioles and midveins of leaves.
Symptoms	Colorful yellow to reddish lesions on leaves, depending on cultivar; premature defoliation may occur.	Colorful yellow to reddish lesions on leaves, depending on cultivar; swelling of petioles; premature defoliation may occur.	On apple, fruit are distorted but foliar lesions are rare; on other hosts, stems and thorns develop swellings; twig dieback can occur; fruit and other infected tissues are covered with aecia.
Appearance of Aecia	Short tubes, approx. $^1/_8$ inch long.	Long tubes, up to ½ inch long.	Long tubes, up to ½ inch long.
Evergreen (Juniper) Hosts	Mainly Eastern red cedar and some ornamental junipers.	Eastern red cedar, Chinese, low, creeping, and savin junipers.	Eastern red cedar, common, creeping, and savin junipers.
Gall Shape and Appearance	Kidney shaped to round, pea to golf-ball in size; depressions are visible where telial horns develop the following spring.	Small, brown galls from $^1/_8$ - $^9/_{16}$ inch in diameter; they can appear flattened on the side attached to the twig.	Subtle, elongated swelling of the twig; some cracking and roughness to the bark.
Number of Years Telia are Produced	One year, usually the spring following gall development.	May produce telia for several growing seasons or years.	One or more years (can be as long as 20 years).
Twig Death	Twig dieback commonly occurs.	Seldom results in twig dieback.	Twig dieback can occur.
Distance Spores Travel Between Hosts to Cause Infection	Usually within several hundred feet, but reported as far as six miles.	Usually within several hundred feet, but reported as far as 14 miles.	Unknown.