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Cedar-Apple Rust

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Cedar-apple rust is a common plant disease caused by the fungal pathogen *Gymnosporangium juniperi-virginianae*. It infects members of the Rosaceae and Cupressaceae families, primarily apple, crabapple, eastern redcedar, and other juniper species. Cedar-apple rust is a widespread disease across the continental U.S. and is a common issue for apple producers due to the prevalence of redcedar and juniper as ornamental plants in landscapes. Although cedar-apple rust is typically a non-injurious disease on redcedar and juniper, the symptoms can be significant and damaging on apple. This disease has been studied since the early 1900's, and many effective management strategies are in place today to minimize losses in apple production.

Causal Agent

Gymnosporangium juniperi-virginianae is a rust pathogen and as such, it is an obligate biotroph and cannot survive without having a living plant host to complete its life cycle. *G. juniperi-virginianae* is a heteroecious rust fungus, which requires two hosts, primary and alternate, to complete its entire life cycle. Its primary host is always a juniper, including eastern redcedar, while the alternate host is apple/crabapple. The pathogen overwinters in galls on redcedar and other juniper species, which allows it to withstand cold temperatures and reinfect neighboring Rosaceous trees the following spring.

Symptoms and Signs

PRIMARY HOST – REDCEDAR/JUNIPER

Symptoms of the infection appear in early summer, following infection by the pathogen the previous summer, when galls begin to form on the branches of the primary host. The galls first appear as small green or brown-colored swollen areas on the sections of the branch where needle-like leaves are growing. Eventually, these galls grow and become dark brown with a diameter of up to two inches. The galls, which are not always spherical and can have lumpy areas, always have small circular dimples across the surface (Figure 1A).

In temperate areas like Ohio, when spring approaches and rainfall increases, large, gelatinous protrusions will erupt from the dimples along the surface of the gall (Figure 1 B-C). The protrusions are typically bright orange, but the amount of orange pigmentation can vary. These are called telial horns, and are spore producing structures of the pathogen, making them the first sign of a fungal fruiting body post-infection. They can dry out with lack of rain (Figure 1 D) and re-swell many times throughout the spring. After the telial horns release their spores and dry up, the gall will die and may stay on the branch for a year or more. These galls sometimes lead to branch or twig death (e.g., produce tip blight and branch dieback symptoms) where they grow, but no other symptoms or signs are evident on juniper or redcedar.

ALTERNATE HOST – APPLE/CRABAPPLE

Initial symptoms of fungal infection appear on apple and crabapple plants as small chlorotic (yellow) spots, which eventually become orange and develop red rings around the edge (Figure 2). Small, orange or dark-colored, sporulating pustules (spermogonia), develop on these lesions on the upper side of the leaf. A little later, fungal fruiting bodies, called aecia, appear on the underside of the leaf and eventually develop hairy, tube-like growths (Figure 2). The aecia will become evident as relatively thick protrusions on the leaf lesion surface. Extensive infections may cause the plant to drop leaves, severely impacting the plant's photosynthetic ability. On the pome fruits, symptoms begin as small yellow or orange lesions, which eventually grow larger and turn brown. Fruit lesions can also develop tube-like aecia, sometimes in large quantities. On crabapple this gives the little fruits a spiky appearance. These lesions may cause fruit to crack open and the fruit stem may become infected causing early stunting in fruit development (Villani, 2018).

Disease Cycle

Gymnosporangium juniperi-virginianae produces multiple spore types: basidiospores, spermatia, aeciospores, and teliospores. The primary host, redcedar/juniper, becomes infected by aeciospores released from aecia on apple/crabapple (the alternate host) in mid-summer. The pathogen then grows and begins to induce the formation of galls on the tree the following summer, which continue to grow throughout fall and winter. With rainfall increasing in early spring, the galls develop telial horns (Figure 1 B-D), one of several forms of fruiting body produced by many rust fungi. Telial horns produce teliospores for several weeks. Teliospores, once exposed to the air, germinate on the telial horn to produce basidia, each of which produces four basidiospores.

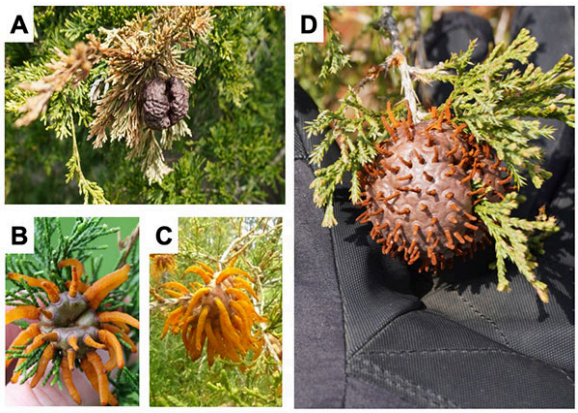

Figure 1: Various stages of telial horn development on redcedar: (A) cedar-apple rust gall before telial horn emergence, (B, C) examples of gelatinous telial horns, and (D) dried-out telial horns. Source: The Ohio State University

Once the basidiospores are released from the top of the basidium they can be dispersed several miles on wind currents (Moffatt et al., 2018). Basidiospores may land on the Rosaceous hosts nearby the infected redcedar/juniper, but conditions must be right for basidiospore germination and subsequent infection to occur. Optimum basidiospore germination occurs when the leaves and/or fruit of the Rosaceous host are coated with a film of water and temperatures are between 56 – 61°F (Olson, 2017). Germination may also occur outside this temperature range, but not at consistent rates. Aldwinckle (1974) suggested that an apple tree is most susceptible to *G. juniperi-virginianae* infection when leaves that are 2-8 days old are present on branches.

Figure 2. Symptoms and signs of cedar-apple rust on crabapple: new lesions (left) and more mature lesions with aecial projections

This infection on the leaves of the alternate host will develop into lesions which form spermogonia, or small pustules, on the upper side of the lesion

surface, which in time leak *from the leaf underside (right). Source:The Ohio State University*
a sticky matrix containing
spermatia, i.e. the sexual
spores (gametes) of the fungus. Spermogonia are attractive to insects, causing them to visit multiple lesions on infected plants, transferring the gametes and causing fertilization (Olson, 2017). The mycelium growing from the fusion of positive and negative spermatia (there is no male and female in fungi) will grow through the leaf and develop the thick tube-like protrusions called aecia on the underside of the lesion discussed above (Figure 2). This fruiting body produces aeciospores, which are released into the air and land on nearby redcedar/juniper. Aeciospores germinate and infect the redcedar or juniper, causing the G. juniperi-virginianae life cycle to repeat itself.

Disease Management

As is true of all diseases, management aims to interrupt the disease cycle. Management of cedar-apple rust can be targeted from multiple standpoints, with options for organic and conventional producers. is important to note management of infection on one host usually involves management strategies that target the other host. Strategies are centered on managing disease incidence to benefit apple/crabapple, as these plants and/or their products are grown commercially and disease not only impacts the ability of the plant to photosynthesize, but also reduces the aesthetic quality of the fruit and the plant in ornamental plantings.

PRIMARY HOST – REDCEDAR / JUNIPER

- **Removal of the primary host** is an old option to manage cedar-apple rust infection of apple. Under this option **all** redcedar or juniper trees within a several mile radii must be removed, thus eliminating the source of basidiospores that could be blown into apple orchards (Villani, 2018). This method is no longer recommended, because the strategy cannot work without complete removal of the primary host. Clearly, this outcome is not attainable, because redcedar and other juniper species are popular ornamental plants, with many located on private properties. For the same reason, planting of primary hosts on one's property should be **avoided at all costs** in the presence of an apple orchard.
- **Gall removal** has also been proposed as a method of disease management. However, disease incidence in apple orchards will not be reduced by gall removal from a few trees if the infection radius is highly populated with redcedar and juniper.
- **Fungicide applications** can also help reduce the presence of galls and prevent introduction of basidiospores into apple orchards, but applications are limited by access to infected plants on private properties, as well as by cost. If this option is

utilized, applications should occur every 14 days from June to September (Olson, 2017). For a list of currently registered fungicides in your state, consult your state Extension specialist or Department of Agriculture and always follow label recommendations.

ALTERNATE HOST – APPLE / CRABAPPLE

- **Fungicide application** to manage cedar-apple rust is commonly included in the disease management programs of many apple production systems. Sterol inhibitors are the most effective fungicides against cedar-apple rust. Typically, sterol inhibitors are incorporated into apple production as a preventative measure to manage many diseases, including cedar-apple rust (Villani, 2018). Fungicide applications typically begin around the time of flowering and continue on a seven-day interval until the telial horns of redcedar or juniper galls finally dry up and fall off (Olson, 2017). At this point, the basidiospores no longer pose a risk to crabapple trees.
- **Host resistance** is an important approach many crabapple and apple producers utilize to manage cedar-apple rust. Several resistant cultivars of juniper and crabapple are available (Table 1) and can be a great addition to disease management; however, more trials are needed for clarity on the designation of this resistance in crabapple. Many popular apple varieties, including 'Golden Delicious,' are highly susceptible, and resistant cultivars are not available (Villani, 2018). If your orchard has high disease incidence, consider choosing resistant varieties in future plantings.
- **Bloom thinning,** along with lime sulfur or a labelled biofungicide, is a proposed method for disease management in organic apple production systems. By thinning blooms on apple branches, airflow improves, and allows blooms and eventually fruits, to dry out more quickly. This reduces the chance of basidiospore germination on apple fruits by limiting the amount of time a water film is present on fruit (Peck et al., 2017).

Conclusions

Cedar-apple rust is a common disease that apple, crabapple, and ornamental plant producers, landscape managers, and property owners must constantly deal with across the continental U.S. Although somewhat disfiguring, overall cedar-apple rust is not a harmful disease of redcedar or juniper, but the prevalence of symptoms (and associated signs) on these hosts can have a drastic impact on the amount of infection on apple trees. The pathogen has a complex life cycle and may appear difficult to manage, but effective strategies have been incorporated into many modern disease management plans. Apple producers have many different options, depending on the extent of infection and the type of production. Of these options, host resistance is a primary strategy to consider when producing apples in organic or conventional orchards or

managing ornamental landscapes. Planting resistant varieties will drastically reduce the impact and presence of disease on all hosts.

Table 1: Known resistant species and varieties (single quotation mark) of crabapple and juniper to the pathogen G. juniperi-virginianae. Note: Resistant does not necessarily mean immune, i.e. resistant plants may still get infected but normally to a much less significant extent than susceptible species/varieties. Adapted from Wallis and Lewandowski, 2008

Resistant Malus spp. (crabapple)	
'Beverly', 'Candied Apple', 'Dolgo', 'Eleyi', 'Inglis', 'Liset', 'Mt. Arbor', 'Narragansett', 'Persicifolia', 'Red Jewel', 'Robusta', 'Royalty', 'Snowdrift', 'Special Radiant', 'Zumi'	
Resistant Juniperus spp. (juniper)	
Species	**Cultivars**
J. ashei	N/A
J. chinensis	'Fermina', 'Fortunei', 'Hetzii', 'Japonica', 'Keteleeri', 'Leeana', 'Mas', 'Oblonga', 'Pendula', 'Pfitzeriana', 'Pfitzeriana compacta', 'Pfitzeriana glauca', 'Plumosa aurea', 'Pyramidalis', 'Sargentii', 'Sargentii variegata', 'Sargentii watereri'
J. communis	'Aurea', 'Aureo-spica', 'Cracovia', 'Depressa', 'Hibernica', 'Oblonga pendula', 'Pyramidalis', 'Saxatilis', 'saxatilis Pallas', 'Suecia', 'Suecia nana'
J. conferta	N/A
J. formosana	'Hyata'
J. horizontalis	'Admirabilis', 'Adpressa', 'Argenteus', 'Douglasii', 'Eximius', 'Filicinus', 'Glomerata', 'Lividus', 'Petraea', 'Plumosa'
J. procumbens	(= J. chinensis var. procumbens)
J. rigida	N/A

J. sabina	'Broadmoor', 'Fastigiata', 'Knap Hill var. Tamariscifolia', 'Skandia'
J. squamata	'Albo-variegata', 'Fargesii', 'Mereri', 'Wilsonii'
J. virginiana	'Aurea', 'Berg's Rust Resistant', 'Burkii', 'Globosa', 'Kosteri', 'Pseudocupressus', 'Pyramidalis', 'Skyrocket', 'Tripartita', 'Venusta'

References

Aldwinckle, H.S. (1974). Effect of leaf age and inoculum concentration on the symptoms produced by *Gymnosporangium juniperi-virginianae* on apple. *Annals of Applied Biology*, 80: 147-153.

Moffatt, K., Flores, C.M., Andreas, P., Kisiala, A., Neil Emery, R.J. (2018). Phytohormone profiling reveals fungal signatures and strong manipulation of infection cycle in the *Gymnosporangium juniperi-virginianae* dual-host plant system. *Botany*, *96:* 57-65.

Olson, J. (2017). Cedar-apple rust [fact sheet]. https://extension.okstate.edu/fact-sheets/cedar-apple-rust.html

Peck, G.M., DeLong, C.N., Combs, L.D., Yoder, K.S. (2017). Managing apple crop load diseases with bloom thinning applications in an organically managed 'Honeycrisp'/'MM.111' orchard. *HortScience,* 52(3): 377-381.

Villani, S. (2018). *Cedar apple rust* [fact sheet]. content.ces.ncsu.edu/cedar-apple-rusts.

Resources

Koetter, R., Grabowski, M. (2019). . extension.umn.edu/plant-diseases/cedar-apple-rust#managing-rust-on-apples%2C-hawthorns%2C-and-other-plants-in-the-rosaceae-family-1172760.

Missouri Department of Conservation. (n.d.). *Cedar apple rust*. Retrieved from mdc.mo.gov/discover-nature/field-guide/cedar-apple-rust.

Pady, S.M., Kramer, C.L. (1971). Basidiospore discharge in *Gymnosporangium. Phytopathology*, 61: 951-953.

Voyle, G. (2016). *Cedar-apple rust: a tale of a fungal disease with two hosts* [Fact sheet]. canr.msu.edu/news/cedar_apple_rust_a_tale_of_a_fungal_disease_with_two_hosts.

Wallis, C. and Lewandowski, D.J (2008). *Cedar Rust Diseases of Ornamental Plants* [Fact sheet]. woodlandstewards.osu.edu/sites/woodlands/files/d6/files/pubfiles /3055%20cedar%20rust.pdf

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