New York State Integrated Pest Management Program
Cornell Cooperative Extension

TREE FRUIT

Cedar Apple Rust

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Cedar apple rust affects the foliage and fruit of apples (*Malus domestica*) and other members of the family Rosaceae (e.g. crabapple). On susceptible varieties, fungal infections render the apple fruit unacceptable for fresh market and severe foliar infection can lead to premature defoliation, thus negatively affecting both fruit quality and tree health. This disease can be especially challenging to manage on susceptible varieties because the disease's symptoms and signs only appear after the point at which treatments should have been applied.

Causal Agent

The fungal pathogen, *Gymnosporangium juniperi-virginianae*, requires an alternate host to complete its lifecycle. Eastern red cedar (*Juniperus virginiana* L.) and other *Juniperus* species serve as alternate hosts. The disease impact on these conifers is important to foresters, arborists, and landscape architects. *Gymnosporangium juniperi-virginianae* occurs throughout the North American continent east of the Rocky Mountains and the disease is particularly prevalent and severe wherever apples, crabapples and junipers grow near to one another in farm, landscape, and forest. It should be noted that several species of *Gymnosporangium* are found in North America and can cause rusts on *Malus* species and other members of the Rosaceae; most have *Juniperus* species as their alternate hosts.

Symptoms & Signs

Gymnosporangium juniperi-virginianae produces distinctive yellow-orange lesions sometimes with a red halo or margin on the upper sides of leaves (Fig. 1a) and on fruit (Fig. 2) that become evident about one to two weeks after petal fall. Resistant cultivars' leaves may develop small, necrotic spots with an orange center, indicating the infection was halted by the plant's resistance response. Within lesions on susceptible cultivars' leaves and fruit, orange-brown pustules (pycnia) develop that exude tiny, orange droplets. By mid- to late summer, yellow-brown lesions will have formed on the undersides of the leaves. These lesions develop a ring of dark brown, tubular structures (aecia) (Fig. 1b) that release light brown spores (aeciospores), which infect eastern red cedar. Aecia only rarely form on fruit.

On eastern red cedar, large, round, woody galls ("cedar apples") form on actively growing shoots and twigs (Fig. 3a). In the second year after infection, these galls develop horn-like structures called telia. Telia, when dry or newly growing, will appear as dark brown threads. During wet, spring weather these telial horns swell, becoming

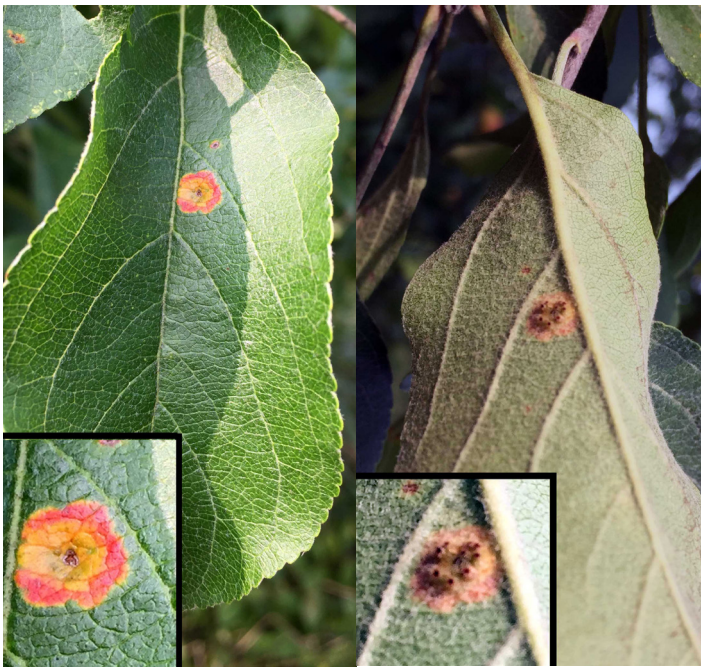

Figure 1. (a) Yellow-orange lesion with red halo, the characteristic symptom of cedar apple rust infection on the upper surface of apple leaves. **(b)** Apple leaf underside revealing the aecia, which produce aeciospores that spread the disease to its alternate host, eastern red cedar *(Juniperus sp.)*. Photo: N. Knight, Plant Pathology, Cornell U.

Figure 2. Cedar apple rust pycnia on a young apple fruit and fruit stem. Photo: K. Cox.

gelatinous and orange in color (Fig. 3b, c). Telia produce spores in the spring that infect apple leaves and fruit.

Gymnosporangium juniperi-virginianae spends two winters in the galls on eastern red cedar before developing telial horns during the second spring (Fig. 3). During rains the horns swell and expose the teliospores, which germinate to produce the basidiospores that infect apple. After a 4-hour wetting period with temperatures averaging between 52-75°F (11-24°C) basidiospores form and discharge into the air. Five to seven hours of wetting is required at lower temperatures 50°F (10°C); no basidiospores form below 46°F (8°C) or above 75°F (24°C). Basidiospores can spread via wind over a half mile (1 km) to developing apple leaves and young fruit. The basidiospores need a film of water on the susceptible plant surface to germinate and cause infection.

Apple leaves are most susceptible to infection when they are 4- to 8-days old. Fruit infections typically occur from tight cluster to petal fall. Infection conditions, hours of wetting and temperature, required for cedar apple rust have been defined (Table 1). One to two weeks following infection, the yellow-orange pycnial lesions develop on leaf upper surfaces and fruit (Fig. 1a and c). In these same lesions the pycniospores contribute to the development, four to six weeks later, of the aecia on the undersides of the leaves (Fig. 1b). The aecial lesions produce aeciospores that release into the air during dry conditions in the late summer months. Aeciospores landing on eastern red cedar may germinate, infect, and lead to the formation of new galls.

Management

Planting resistant apple cultivars, removing eastern red cedar adjacent to orchards, and treating apple trees with appropriate fungicides in the spring when rainy, cool weather favors infection will all contribute to effective management of cedar apple rust.

Cultivars with a high level of resistance include: cvs. Akane, Delicious, Early McIntosh, Empire, Golden Supreme, Gravenstein, Jerseymac, Jonamac, Liberty, Macoun, McIntosh, Milton, Niagara, Nova Easygro, Novamac, Paulared, Priscilla, Puritan, Spartan, Tydeman's Early Worcester, and Viking. Even resistant cultivars may need fungicide protection when disease pressure is high from nearby eastern red cedar and prolonged periods of rainy, cool weather occur in spring.

Highly susceptible cultivars that warrant a fungicide program include: cvs. Burgundy, Braeburn, Cameo, Cortland, Golden Delicious, Gala, GoldRush, Jonagold, Jonathan, Julyred, Lodi, Macfree, Monroe, Mutsu, Northern Spy, Lodi, Prima, Quinte, Rhode Island Greening, Rome Beauty, Sir Prize, Stayman, Twenty Ounce, Vista Bella, Wayne, Wealthy, and York Imperial.

Figure 3. (a) Cedar apple rust galls form on eastern red cedar starting in the autumn months after initial infection. Galls continue to grow through spring, summer and fall of the following year, allowing the fungus to overwinter through two winters. **(b)** Early in the second spring, the mature galls begin to exude telial horns. **(c)** By mid-spring telial horns have fully developed. During wet weather they become gelatinous and orange whereupon they release teliospores that generate subsequent basidiospores to spread the infection to an apple host. Telial horns can dry down and rehydrate to produce repeated cycles of basidiospores before the spore supply is exhausted and the gall dies out. Photos: D. Strickland (a), K. Cox (b, c).

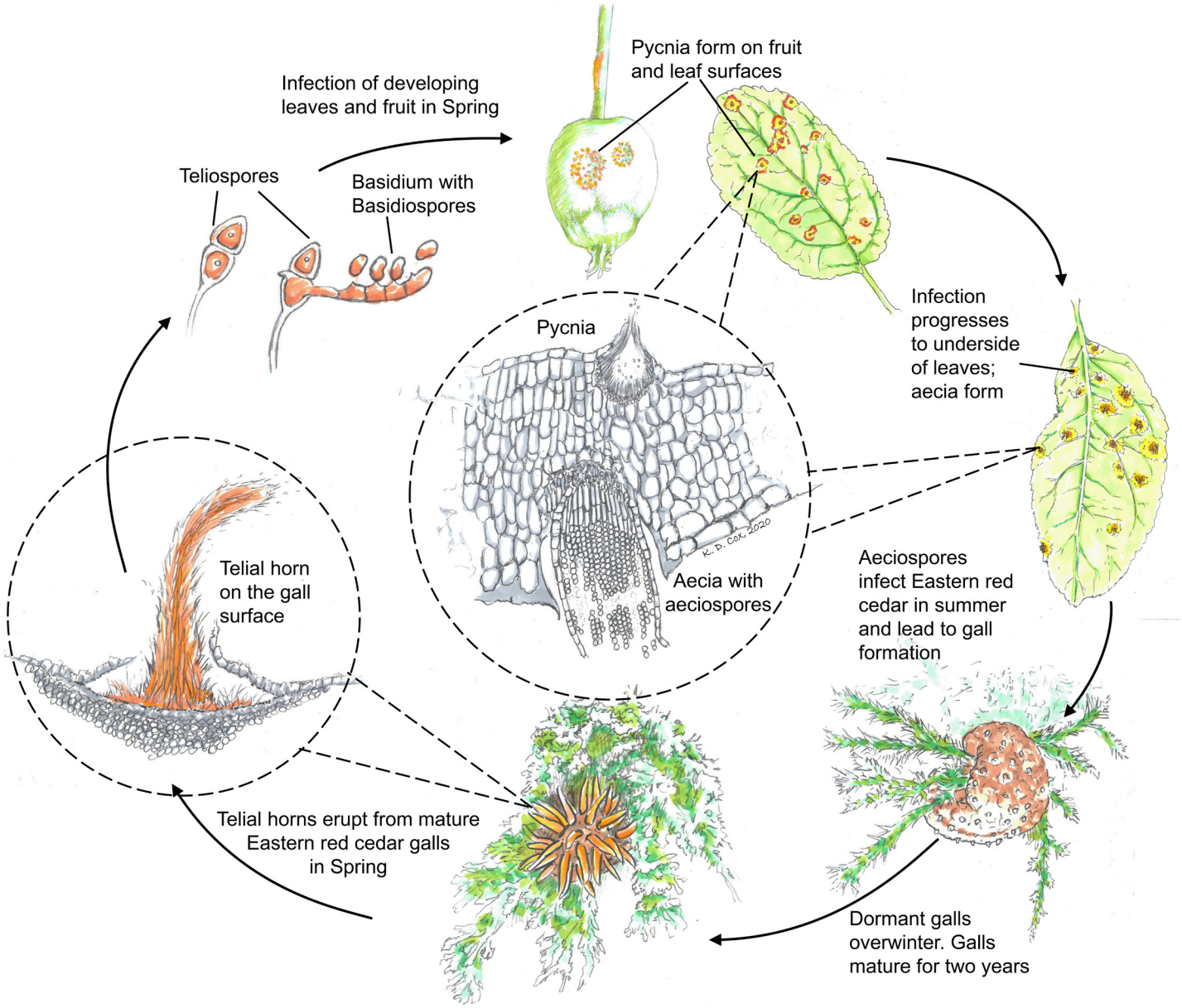

Figure 4. Disease cycle of *Gymnosporangium juniperi-virginianae,* causal fungus of cedar apple rust. Illustration: K. Cox.

The susceptibility of modern, popular cultivars such as cvs. EverCrisp, Honeycrisp, NY1 (SnapDragon), and SweeTango to cedar apple rust has not been definitively tested. However, anecdotal evidence suggests that these cultivars are relatively resistant.

Removing eastern red cedar trees in proximity to apple orchards will help break the life cycle of the pathogen. The rust fungus only produces spores that can infect apple trees on its alternate host. To completely eliminate the threat to apples coming from the alternate host, eastern red cedars need to be removed from within approximately a mile radius around the orchard. In the landscape, desirable eastern red cedars can be pruned meticulously to remove galled branches in late autumn, before the telial horns form in spring.

Fungicides effective against cedar apple rust are in the classes of the demethylation inhibitors (DMIs) and the succinate dehydrogenase inhibitors (SDHIs). The DMIs remain the most effective fungicides for managing cedar apple rust. However, active ingredients within the SDHI and DMI classes differ in their effectiveness to cedar apple rust and some may be ineffective. Cedar apple rust also may be kept in check by applications of mancozeb, a broad-spectrum protectant fungicide, used to manage apple scab in the early part of the season, which also works against cedar apple rust.

In organic production, cedar apple rust may prove a greater management challenge. Fortunately, however, biopesticides, resistance inducer fungicides, and organic copper formulations may prove effective in combination with host resistance and removal of eastern red cedar.

To best manage cedar apple rust on susceptible varieties, use effective fungicides as per the label directions beginning at tight cluster and continuing through the 2nd week after petal fall. Monitor weather forecasts to protect tissues prior to spring rains with favorable temperatures (Table 1) to reduce the number of applications needed and achieve sustainable management. Refer to the Cornell Pest Management Guidelines for Commercial Tree Fruit Production (updated yearly) for specific fungicides and application timings.

Table 1: Temperature and Moisture Requirements for Cedar Apple Rust Infection

(°F)	(°C)	Basidiospore Formation	Light Infection	Severe Infection
36	2	NB	24	NSI
39	4	NB	12	24
43	6	NB	8	10
46	8	7	6	7
50	10	5	5	6
54	12	4	4	5
57	14	4	3	5
61	16	4	3	4
64	18	4	3	4
68	20	4	2	4
72	22	4	2	4
75	24	4	2	4
>79	>26	NB	NI	NI

NB: No basidiospores formed at this temperature.

NSI: No severe infection observed at this temperature

NI: No infections observed at this temperature.

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