



Bitter Rot of Apple

Kimberly Leonberger
Extension Associate

Madison McCulloch
Graduate Research Assistant

Nicole Gauthier
Extension Plant Pathologist

INTRODUCTION

Bitter rot is the most common fruit rot of apple in Kentucky. Trees in both commercial and residential plantings can suffer devastating losses. Growers consider bitter rot the most important fruit rot and the second most destructive disease in Kentucky apple orchards. Yield losses can range from 10% to 100%.

SYMPTOMS

Bitter rot lesions (spots) begin as small, sunken, localized areas on outer surfaces of fruit. As lesions mature, they remain sunken and circular, and some spots may develop red halos (FIGURE 1). Over time, lesions darken to brown and expand to develop a bullseye pattern. During periods of rainy weather, salmon or pink spores may appear in circular

patterns (FIGURE 2). Cross sections of fruit reveal an internal rot with a “V” shape that is brown and firm (FIGURE 3). Symptoms of bitter rot may not appear immediately after infection and can take several days to two months to become visible. Symptoms begin to appear in early to mid-summer, as early as mid-June in Kentucky, and disease often increases as fruit ripen and harvest approaches. Infected fruit may fall prematurely or remain attached to trees as mummies (dried fruit) (FIGURE 4). Symptoms may also develop in storage after harvest.

CAUSE OF DISEASE

Bitter rot is a fungal disease caused by multiple species within the *Colletotrichum acutatum* and *Colletotrichum gloeosporioides* sp. complexes (FIGURE 5). Each complex contains 34 and 38



FIGURE 1. THE FIRST SYMPTOMS OF BITTER ROT ARE SMALL TO MEDIUM-SIZED, SLIGHTLY SUNKEN LESIONS.



FIGURE 2. SUNKEN LESIONS WITH BULL’S-EYE APPEARANCE ARE TYPICAL OF LATE-SEASON SYMPTOMS OF BITTER ROT.



FIGURE 3. INTERNAL V-SHAPED ROT IS AN IDENTIFYING CHARACTERISTIC OF BITTER ROT.



FIGURE 4. INFECTED FRUIT MAY REMAIN ATTACHED TO TREES AS MUMMIES AND SERVE AS INOCULUM SOURCES FOR SUBSEQUENT SEASONS.

individual species, respectively. Previous literature (and some current publications) reference species complex instead of the specific species within the complex. To date, 12 individual species of *Colletotrichum* have been identified as fruit rot pathogens in the Southeastern U.S. (TABLE 1). In Kentucky, six individual species are known to cause apple bitter rot. Species identification is important because individual species exhibit differences in:

- Spore production
- Competition/fitness
- Infectivity and aggressiveness
- Host preference
- Temperature preference
- Fungicide sensitivity

DISEASE DEVELOPMENT

Bitter rot fungi can overwinter in fallen fruit, mummies (dried fruit that remain attached to the tree), and dead or diseased wood (e.g. fire blight cankers). Research has confirmed the presence of dormant fungi on a wide range of apple tree tissues in late winter and early spring (before plant growth resumes), particularly on fruit mummies and their pedicels, as well as in fire blight-infected shoots (FIGURE 6).

When weather warms, fungi produce fruiting structures (acervuli) on the surface of plant tissues. During wet conditions, these structures absorb water and release infective spores (conidia). Some species



FIGURE 5. DIFFERENCES IN APPEARANCE BETWEEN COMPLEXES CAN OFTEN BE OBSERVED BY SPORULATION PATTERNS. SPECIES WITHIN THE *C. ACUTATUM* COMPLEX PRODUCE ORANGE CONIDIAL (SPORE) MASSES DURING WET CONDITIONS (LEFT), WHILE *C. GLOEOSPORIOIDES* COMPLEX SPECIES DEVELOP BLACK ACERVULI (FRUITING STRUCTURES) AND NO ORANGE CONIDIAL MASSES (RIGHT).

TABLE 1. COLLETOTRICHUM SPECIES THAT CAUSE BITTER ROT OF APPLE AND OTHER FRUIT ROTS IN THE EASTERN U.S., PRESENTED BY COMPLEX.

<i>Colletotrichum</i> Complex	Species
Acutatum Complex	<i>C. fioriniae</i> *
	<i>C. nymphaeae</i> *
Gloeosporioides Complex	<i>C. aenigma</i>
	<i>C. conoides</i>
	<i>C. fructicola</i> *
	<i>C. gloeosporioides</i>
	<i>C. henanense</i>
	<i>C. kahawae</i>
	<i>C. sp. kahawae</i> clade*
	<i>C. nupharicola</i>
	<i>C. siamense</i> *
	<i>C. theobromicola</i> *

* SPECIES HAS BEEN FOUND IN KENTUCKY.

produce orange to salmon-colored mucilage that carries spores as it oozes from lesions. These spores may be blown or splashed onto susceptible plant tissue within short distances, and wind-driven rain may move spores across an orchard. Initial infections can occur as early as bloom, with additional infections possible throughout the growing season and into harvest. Research is ongoing to determine when the fungus breaks dormancy in spring and specific times of sporulation and infection of flowers and fruit.

As with all fungal pathogens, these fungi favor wet conditions and moderate temperatures. Thus, bitter rot disease is more severe during wet seasons. Disease can also be more severe in dense orchards where there is limited air circulation, restricted sunlight, and high humidity.

Fruit infected in the field can develop symptoms in storage and shorten shelf-life.

HOST RANGE

Colletotrichum fungi are widespread; they are found on a variety of hosts, in different geographical regions, and under a range of ecological settings. Thus, they are termed as “cosmopolitan” fungi. Fruit other than apple may serve as hosts for the bitter rot-causing fungi. Other fruit crops, such as blueberry, grape, pear, and strawberry are commonly affected by the same pathogens that are responsible for bitter rot, potentially extending the period of infection risk and serving as inoculum sources for apple.

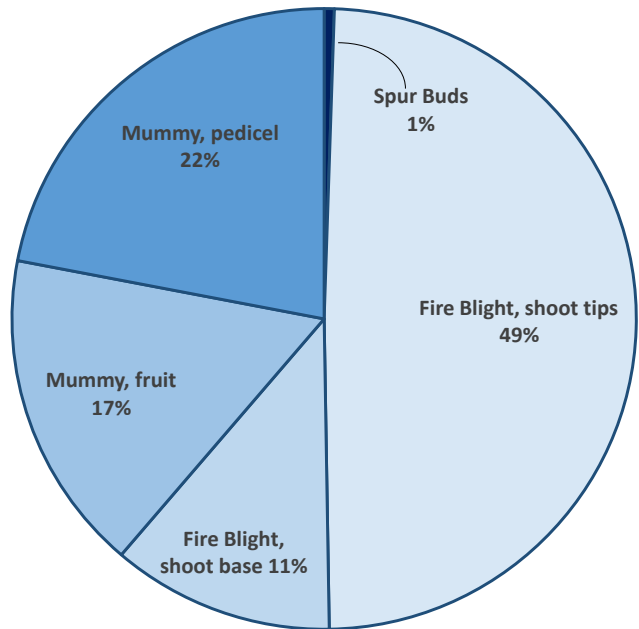


FIGURE 6: KENTUCKY APPLE ORCHARD SURVEY RESULTS: PERCENT OF SAMPLE TISSUE IN WHICH VIABLE BITTER ROT FUNGI WERE RECOVERED DURING TREE DORMANCY. IN THIS STUDY, NO BITTER ROT FUNGAL PROPAGULES WERE RECOVERED FROM TERMINAL BUDS, LATERAL BUDS, OR FALLEN FRUIT RESIDUE.

A survey of Kentucky orchards (2011-2018) helped us better understand the distribution of *Colletotrichum* species among common fruit types (TABLE 2). The two most common species that cause bitter rot in Kentucky are:

- *C. fioriniae* – Pathogenic on apple, blueberry, grape, peach, and strawberry; the most prevalent species found in apple. High spore production; orange spore masses visible on outer fruit surfaces, especially under wet conditions; more aggressive and may outcompete other species.
- *C. siamense* – Pathogenic on apple, blueberry, grape, peach, and strawberry. Lesions expand rapidly and are typically larger than those produced by other species. Fewer spores produced per lesion compared to other species; black fruiting structures (acervuli) are visible on outer fruit surfaces, arranged in concentric rings.

In addition to fruits, other plant species may become infected by the *Colletotrichum* fungi that cause bitter rot. These plants may serve as alternative or reservoir hosts. Alternative hosts can become infected and develop leaf spots or dieback. Reservoir hosts can also harbor endophytic infections in which no symptoms develop. Research has confirmed the presence of *C. fioriniae*, the most common *Colletotrichum* species on apple in Kentucky, in

TABLE 2. PERCENT DISTRIBUTION OF COLLETOTRICHUM SPECIES IN KENTUCKY BY FRUIT TYPE.

<i>Colletotrichum</i> Species	Apple Bitter Rot	Peach Anthracnose	Strawberry Anthracnose (fruit rot)	Strawberry Crown Anthracnose	Blueberry Ripe Rot
<i>C. fioriniae</i>	71	83	4	-	100
<i>C. nymphaeae</i>	3	-	91	~50	-
<i>C. theobromicola/fragariae</i>	2	-	-	-	-
<i>C. siamense</i>	20	17	4	~50	-
<i>C. fructicola</i>	4	-	1	-	-
<i>C. camelliae</i>	1	-	-	-	-

TABLE 3. ALTERNATIVE AND RESERVOIR HOSTS OF COLLETOTRICHUM FIORINIAE.

Alternate & Reservoir Hosts	
celery	peony
chickweed	plantain
dandelion	poison ivy
dodder	white clover
hemp	wild grape
honeysuckle	insects (scale, gall wasp)

common trees, weeds, and even insects (TABLE 3). It is unclear whether infections can move from alternative hosts to fruit; this research is ongoing.

DISEASE MANAGEMENT

Sanitation and other cultural practices are critical for management of bitter rot. These practices, combined with fungicides, can significantly reduce disease impact. Cultural practices should be considered for all orchard types, whether conventional or organic, sprayed or non-sprayed.

Sanitation

Sanitation practices should be implemented throughout the entire growing season to remove potential inoculum sources. Scout trees or orchards frequently to identify diseased fruit early in the season. Remove and discard all diseased fruit immediately. Prune trees to remove cankers and other dead wood that may harbor fungi. Pruning is typically completed during winter months, but damaged or diseased tissue should be removed as

soon as it is identified. Diseased tissue, including fruit and woody cuttings, should be destroyed away from the orchard. At the end of the growing season, all fallen or hanging fruit should be collected and destroyed.

Cultural Practices

Plan orchard spacing and orientation to provide air circulation and to encourage rapid drying of morning dew or rain. Tree vigor should be maintained through avoidance of excessive pruning and tree crowding. Hand or chemically thin fruit in heavy cropping years to reduce tree stress. Manage weeds and potential alternative and reservoir hosts that may serve as sources for inoculum.

Cultivar Susceptibility

While there are no cultivars that are resistant to bitter rot, some cultivars are more tolerant than others. Avoidance of the most susceptible cultivars helps reduce the amount of disease (TABLE 4).

Susceptible Cultivars
Arkansas Black
Cripps Pink/Pink Lady
Empire
Enterprise
Fuji
Gala
Ginger Gold
Golden Delicious
Honeycrisp
Jonagold

TABLE 4. APPLE CULTIVARS MOST SUSCEPTIBLE TO BITTER ROT, AS OBSERVED IN KENTUCKY ORCHARDS.

Fungicides

Fungicides are not curative, and they are less effective when proper sanitation and cultural practices are not used. Application of fungicides should be timed to coincide with fungal activity for prevention of infections. Spore trapping research has confirmed airborne spores as early as petal fall, suggesting that the fungus is active about 8 weeks before the first fruit rot symptoms develop. Fungicide applications should begin at bloom or petal fall when the fungus breaks dormancy and becomes active, and they should continue until harvest, especially when weather is rainy.

Current fungicide efficacy data is presented in TABLE 5. In general, some classes (FRAC groups) are considered more effective than others. The M-class fungicides captan and mancozeb are effective, but they are not rainfast (i.e. they wash off in the rain). The QoI class fungicides (FRAC 11) are also effective products for prevention and management of bitter rot. They are locally systemic (fungicide can move from one part of the leaf to another) and thereby rainfast. The SDHI (FRAC 7) and FRAC 29 groups have good to moderate efficacy and serve as suitable rotational products. Fungicide chemistries and efficacy data can change rapidly; contact your local county Extension agent for up-to-date information and for assistance with specific fungicide recommendations.

TABLE 5. EFFICACY OF FUNGICIDES FOR MANAGEMENT OF BITTER ROT BY MODE OF ACTION (FRAC GROUP). THESE EFFICACY RATINGS ARE "GENERAL" AND NOT SPECIES-SPECIFIC.

FRAC	Fungicide*	Active Ingredient	Efficacy **	Notes
M	Mancozeb, Manzate	mancozeb	E	Not rainfast
M	Captan + Mancozeb	captan + mancozeb	E	Not rainfast
M	Captan	captan	G-E	Not rainfast
M+33	Captan + ProPhyt	captan + phosphorus acid	E	Captan not rainfast Phosphorus acid is systemic
7+11	Merivon	fluxapyroxad + pyraclostrobin	E	Systemic
11	Flint	trifloxystrobin	E	Systemic
7	Aprovia	benzovindiflupyr	G-E	Systemic
7	Fontelis	penthiopyrad	G	Systemic
7+11	Luna Sensation	fluopyram + trifloxystrobin	G	Systemic
7+11	Pristine	pyraclostrobin + boscalid	G	Systemic
11	Sovran	kresoxim-methyl	G	Systemic
29	Omega	fluazinam	G	Systemic
M	Ziram	ziram	G	Not rainfast
1	Topsin M	thiophanate-methyl	G-P	Systemic Efficacy depends upon fungal
3	Rally	myclobutanil	P	Systemic Efficacy depends upon fungal species
3	Bayleton	triadimefon	0	
3	Indar	fenbuconazole	0	
3	Procure	triflumizole	0	
3	Rhyme	flutriofol	0	

*FUNGICIDE NAMES ARE INCLUDED AS EXAMPLES, OTHER SIMILAR PRODUCTS AVAILABLE. THIS TABLE MAY NOT REPRESENT ALL APPLICABLE PRODUCTS.

** EFFICACY RATING: E-EXCELLENT, G-GOOD, F-FAIR, P-POOR, 0-NO EFFICACY

ADDITIONAL RESOURCES

- Fruit, Orchard, and Vineyard Sanitation (PPFS-GEN-05)
<http://plantpathology.ca.uky.edu/files/ppfs-gen-05.pdf>
- Backyard Apple Disease & Pest Management Using Cultural Practices (PPFS-FR-T-21)
<http://plantpathology.ca.uky.edu/files/ppfs-fr-t-21.pdf>
- Simplified Backyard Apple Spray Guides (PPFS-FR-T-18)
<http://plantpathology.ca.uky.edu/files/ppfs-fr-t-18.pdf>
- Effectiveness of Fungicides for Management of Apple Diseases (PPFS-FR-T-15)
<http://plantpathology.ca.uky.edu/files/ppfs-fr-t-18.pdf>
- Commercial Fruit Pest Management Guide (ID-232)
<http://plantpathology.ca.uky.edu/files/id-232.pdf>

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