

Bull's Eye Rot

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Bull's eye rot (BER) is a continuous threat to apple and pear storability in the PNW and in many other growing regions. Recent surveys from Washington State showed that BER accounted for 8 to 10% of overall decayed fruit and 40% of the surveyed orchards had BER at frequencies ranging between 1% and 75% (Amiri and Ali 2016). Some cultivars, such as Golden Delicious and Pinata are highly susceptible to *Neofabraea* spp., but other cultivars such as Fuji, Cripps Pink, and Granny Smith can also be at risk, especially when rainy conditions occur before harvest.

Casual Organism

Bull's eye rot is a major economic postharvest disease of apple and pear that can be caused by four *Neofabraea* species; *N. perennans* Kienholz, *N. alba* E.J. Guthrie, *N. malicorticis* H.S. Jacks and *N. kienholzii* Seifert, Spotts & Lévesque. In central Washington, BER is predominantly caused by *N. perennans* which also causes perennial cankers on apple trees. *Neofabraea malicorticis* is more widespread in western Washington where it causes Anthracnose cankers in addition to BER. *Neofabraea alba* is found more often on pear in Oregon, whereas *N. kienholzii* is the latest BER-causing species to be reported in the PNW.

Symptoms

BER symptoms of infections originating from lenticels show lesions that are depressed, circular, flat to slightly sunken with a light brown to dark brown halo around a lighter brown to tan center. Several spots may be visible on a single fruit. Infections that start from the stem-end or calyx-end will have the same coloration but are not sunken. Decayed tissue is dark brown in the inside with a dense consistency and a clear margin between decayed and healthy tissue. Usually, decayed tissue does not readily separate from the healthy tissue. BER lesions progress slowly in cold storage and as decay advances, cream-colored spore masses may appear at the center of the lesion (Fig.1). It is very difficult to differentiate between BER infections caused by the different *Neofabraea* species on fruit. Lesions of *N. alba* may look much paler than that of lesions caused by *N. perennans*, whereas *N. malicorticis* tend to show gray acervuli (small asexual fruiting body shaped like a pimple) that are concentrically distributed at the center of the lesion.

Infection cycle of *Neofabraea* species

In central Washington State where the majority of apple and pear orchards are planted, BER is mainly caused by *N. perennans*, which seems to be better adapted to the dry and semi-arid climate. BER of pear in Oregon was found to be often caused by *N. alba*. *Neofabraea perennans* can cause perennial cankers, on the tree, on which the fungus overwinters as acervuli and from which conidia are released when conditions become favorable in the spring and summer of the following season. Besides cankers, *Neofabraea* species can overwinter, as asymptomatic infections, in mummified fruits, pruned wood, leaf litter, and on grass around the orchard (Kohl et al. 2018). On pear trees, *Neofabraea* spp. may survive on dead bark.



A: BER early infection starting from a wound. Note light brown in the center and the darker halo



B: BER infection originating from a wound. Acervuli start to appear.



C: BER originating from a lenticel infection on Gala.



D: BER originating from a lenticel infection on Gala. Note the difference with Photo in C.



E: BER starting from stem-bowl on Gala. Firm consistency.



F: BER starting from the calyx-end on Golden Delicious. Firm consistency.



G: Advanced stage of BER on Fuji. White mycelium and cream-colored spore masses present.



H: Cross-section of a Fuji apple showing internal symptoms of BER starting from a lenticel and stem-bowl. Note the sharp margin.



I: Advanced stage of BER on d'Anjou pear. Cream-colored spore masses present at the center of the sunken lesion.

Figure 1. Symptoms and signs of Bull's eye rot (*Neofabraea* spp.) on apples and pears. Photo credit to Achour Amiri (WSU-TFREC).

Inoculum of *Neofabraea* spp. may also come from alternative hosts such as western crabapple (*Malus fusca*), which is thought to be the original host of anthracnose canker (Aguilar et al. 2017). The primary and secondary inoculums are water-splashed to limbs and fruits to cause infections between petal fall and harvest, when fruit are more susceptible. Infections are more frequent in rainy seasons and on late cultivars that tend to receive more rain. The fungus only infects fruit preharvest, and because of the dry growing season in the region, infections remain latent with symptoms expressed only after 3-4 months of storage. BER incidences as high as 20% can be seen especially in rainy seasons and on susceptible cultivars. BER does not spread from decayed to healthy fruits inside the bin in cold storage. The fungus grows between 0°C and 25°C (32°F-82°F), with the optimal temperature being 20°C (68°F). Growth declines significantly at temperatures around 30°C (>86°F) and above.

Control

Cultural Control: It is important to establish new plantings with clean stock free of visible cankers. Scout orchards, especially new ones, regularly for cankers. Early detection will help with management. In apple and pear orchards, prune and remove cankered branches to reduce overwintering inoculum and apply fungicides to dead bark to target potential surviving inoculum of *Neofabraea* spp. Water spreads the fungal inoculum and creates conditions conducive for fruit infection. Avoid overhead irrigation and cycle over-tree cooling so that conditions do not remain wet in the canopy for prolonged periods of time. Ideally harvest fruit while they are dry and store immediately.

Chemical Control. Pre and postharvest applications of fungicides are key to effective bull's eye rot management. Before making a spray decision, consider the cultivar and weather conditions occurring during that season, as these two factors have a great impact on BER development in storage. Even though fruit become more susceptible closer to harvest, infection by *Neofabraea* spp. may occur anytime between bloom and harvest. Consider your fungicide timing. Studies have shown that treatments applied 18 weeks before harvest were more effective in controlling BER than those applied two weeks before harvest. The most effective preharvest fungicide is Topsin-M (FRAC 1) but other fungicides, such as Pristine (FRAC 7 + 11), have shown good efficacy levels. The multi-site fungicide Ziram applied within two weeks before harvest has shown variable levels of efficacy against bull's eye rot in the Pacific Northwest but is a good fungicide to include in the spray program alone or tank-mixed with other fungicides to enhance control and mitigate fungicide resistance.

Four different fungicides are currently registered to control postharvest decays of pome fruit (Table 2). Thiabendazole (FRAC 1) is the most effective fungicide against bull's eye rot followed by pyrimethanil (Penbotec). Fludioxonil (Scholar) has a low efficacy against bull's eye rot and it is recommended to apply it in combination with thiabendazole, especially on susceptible cultivars or on lots with known bull's eye rot history. Difenconazole was registered for postharvest application on pome fruit in 2016 and has shown a better efficacy against bull's eye rot compared to Scholar alone. Formulations exist to apply thiabendazole, pyrimethanil, and fludioxonil through thermonebulization (TNB, fog) exist already and a formulation for a fog application of Academy is pending. In Washington State, Academy can be applied via drench at harvest as long as packers can follow specific fungicide waste management practices (<https://agr.wa.gov/wastepesticide>). *Neofabraea* species have a medium risk for fungicide resistance development, therefore, rotation of fungicides from different FRAC groups in orchards and warehouses is important to avoid selection for populations that are resistant to current fungicides especially for FRAC 1 fungicides (thiabendazole, Topsin-M).

Table 1. List and efficacy of fungicides registered to control bull's eye rot and other decay rots preharvest.

Active ingredient	Products with active	FRAC group	Rate/ac	PHI ^a (days)	Registered for		Efficacy against bull's eye rot
					Apple	Pear	
Thiophanate-methyl	Topsin-M 70 WSB	1	0.75-1 lb	1	+	+	Very good
Boscalid	Pristine	7	18.5 oz	0	+	+	Good-fair
Fluxapyroxad	Merivon	7	5.5 fl oz	0	+	+	Unknown
Pyraclostrobin	Pristine, Merivon	11	Check labels	0	-	+	Fair
Fenhexamid	Elevate 50WDG	17	1-1.5 lb	0	- ^b	+	NA
Ziram	Ziram 76DF	M03	6 lb	14	+	+	Good-fair
Captan	Captan 50 WP	M04	6 lb/ 20-400 gal	0	+	-	Fair

^a Preharvest interval^b Allowed in non-bearing apple.**Table 2. List and efficacy of fungicides registered to control bull's eye rot and other decay rots postharvest.**

Active ingredient	Products with active	FRAC group	Rate	PHI ^a (days)	Registered for		Efficacy against bull's eye rot
					Apple	Pear	
Thiabendazole	TBZ, Mertect, eFog-99	1	see label	NA	+	+	Very good
Pyrimethanil	Penbotec, eFog 160	9	see label	NA	+	+	Good
Fludioxonil	Scholar, eFog80,	12	see label	NA	+	+	Low
Difenoconazole + fludioxonil	Academy	3 + 12	16	NA	+	+	Medium
Captan	Captec 4L	M04	1.25 qt	NA	+	+	Low-fair

^a Preharvest interval

For additional information, please consult the [WSU Crop Protection Guide](#)

References

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- Amiri A., and Pandit L.K. 2019. Evaluation of difenoconazole as postharvest fungicide to control ten major pathogens of pome fruit. APS-Pacific Division. Phytopathology 109-11-S3.8.
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- Spotts RA., Seifert KA., Wallis KM., Sugar D., Xiao CL., Serdani M., and Henriquez JL. 2009. Description of *Cryptosporiopsis kienholzii* and species profiles of *Neofabraea* in major pome fruit growing districts in the Pacific Northwest USA. Mycological Research 113:1301-1311.

Use pesticides with care. When mixing and applying pesticides, follow all label precautions to protect yourself and others around you. It is a violation of the law to disregard label directions. If pesticides are spilled on skin or clothing, remove clothing and wash skin thoroughly. Store pesticides in their original containers and keep them out of the reach of children, pets, and livestock.

YOU ARE REQUIRED BY LAW TO FOLLOW THE LABEL. It is a legal document. Always read the label before using any pesticide. You, the grower, are responsible for safe pesticide use. Trade (brand) names are provided for your reference only. No discrimination is intended, and other pesticides with the same active ingredient may be suitable. No endorsement is implied.