

Botrytis Fruit Rot of Strawberry

Production Guideline by Steven T. Koike & Mark Bolda

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The California Strawberry Commission Production Guidelines are produced in cooperation with scientists who conduct research related to strawberry production. These guidelines are a tool for growers, providing critical scientific background information on diseases and pests common to strawberry production in California. For copies of this guideline or others in the series, visit www.calstrawberry.com.

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Introduction and significance

Of the numerous pathogens that cause fruit diseases of strawberry, the gray mold fungus (*Botrytis cinerea*) is the most widespread and important in California and other strawberry growing regions in the world. The disease is called Botrytis fruit rot or gray mold. Botrytis fruit rot is found on strawberry throughout the state and can cause significant loss of pre- and post-harvest fruit because the disease can develop both in the field and during storage and transit. If environmental conditions favor the fungus, it remains one of the most difficult pathogens to control.

Symptoms and Signs

Manifestation of gray mold depends on which part of the strawberry is infected and the physiological status of that tissue. Young, newly expanding leaves can be infected but do not show symptoms because the fungus remains dormant (quiescent or latent) in these tissues. When such leaves are mature and beginning to senesce and decline, the fungus can become active and produce the characteristic gray, velvety growth on the dead portions of the leaf. *B. cinerea* can also infect flowers and cause a blossom blight disease. Symptomatic flowers exhibit brown, discolored lesions on petals, receptacle (the small, green central part of the flower that eventually becomes the fruit), and sepals (Figures 1 and 2). If gray mold continues to develop in the flower, the pathogen will kill the pedicel (the stem attached to the fruit) (Figure 1), causing the entire flower and undeveloped fruit to wither and die.

In many cases, the infected flower will not show symptoms because *B. cinerea* can colonize internal flower tissues but remain dormant. Once these fruits begin to expand and develop, the pathogen becomes active and causes a firm, light brown decay on the calyx end of young fruit (Figure 3) as well



Figure 1. Brown, discolored flower tissues infected with *Botrytis cinerea*.



Figure 2. Brown, discolored flower tissues infected with *Botrytis cinerea*.

as a similar firm decay on white, pink, and red stage fruit. Fully mature red fruit are especially susceptible to *Botrytis* infections following physical damage (Figure 4), in which case the pathogen can rapidly colonize the injured tissue and spread throughout the entire fruit. If environmental conditions favor the fungus, any part of the strawberry plant that is colonized by *B. cinerea* can be covered with the gray, fuzzy growth of the pathogen. On mature red fruit in the field, advanced cases of gray mold will result in the entire fruit covered with a gray carpet of the spores (Figure 5). *Botrytis* that is growing on one diseased fruit will readily grow onto other fruit that are in contact with the infected one; this “nesting” habit results in clusters of diseased fruit (Figure 5). If left on the plant, infected fruit will eventually become shriveled, dried, and hard. On post-harvest fruit in cold storage, gray mold growth may be whiter in color because the pathogen usually needs light to fully develop the gray spores.

Causal Organism

Botrytis cinerea is one of the most common fungal plant pathogens and infects well over 200 different plant hosts. In addition to being an aggressive primary pathogen, *B. cinerea* is a versatile organism, able to grow and reproduce on damaged, senescing, and dead tissues of strawberry, vegetables, and many other plants. *B. cinerea* reproduces primarily by making asexual spores, or conidia. These gray masses of conidia are readily spread by wind, splashing water, and physical/mechanical activity. Under magnification one can see the distinctive “botryose” (from the Greek for “bunch of grapes” and hence is the root word for “Botrytis”) clusters of spores at the ends of the spore-bearing branches (Figure 6). Like many fungi, *B. cinerea* also has a second, sexual form named *Botryotinia fuckeliana* that consists of a tiny mushroom-like structure (apothecium) that contains a different spore type (ascospore). However, this phase apparently has not been found in strawberry fields in California or elsewhere.

Under some conditions, *B. cinerea* can produce an overwintering structure, the sclerotium, which is a hard, black, oblong to spherical structure up to ½ inch in length. Sclerotia can withstand dry, warm, and cold conditions. Under more conducive conditions, sclerotia will germinate to form mycelium that can colonize a host and produce spores. In California, sclerotia are not commonly observed in strawberry fields, though in other countries sclerotia appear to be plentiful and are an important source of primary inoculum.

Recent research has demonstrated that gray mold may be caused by more than one species of *Botrytis*. Some researchers have molecular evidence that *Botrytis cinerea* is actually a complex entity consisting of different but closely related species (*B. cinerea* and *B. pseudocinerea*). While these different species can be separated on the basis of DNA analysis, they are indistinguishable when growing on host plants or in culture. The presence of more than one *Botrytis* species has not yet been documented on strawberry in California but has been found on blueberry in the San Joaquin Valley. Future studies could investigate if more than one *Botrytis* species is present on California strawberry and whether this has any practical implications.



Figure 3. Light brown decay of fruit and pedicel resulting from gray mold infection of the strawberry flower.



Figure 4. Early stages of gray mold on fruit showing sunken lesions and the initial growth of the gray mycelium and spore.



Figure 5. In advanced stages, infected fruit can be covered entirely with *Botrytis* growth that spreads to adjacent fruit by contact (i.e., nesting).

Disease Cycle

The pathogen can be introduced into production fields by several means: (1) transplants often are already contaminated with *Botrytis* spores or colonized by *Botrytis* mycelium growing in senescent and dead leaves and other tissues; (2) overwintering structures (sclerotia) survive in the soil or on plant residues in and around the field; (3) overwintering mycelium is present in dead and decayed residues from the previous crop; (4) active spore-producing *Botrytis* growth is present on adjacent crops, which can include nearby vegetable and second year strawberry plantings.

Under cool, humid, wet conditions, the gray mold fungus from any of these sources will produce masses of conidia that are spread via wind and splashing water onto the strawberry crop. For infection to take place, spores require free moisture on the plant tissues. Therefore, gray mold infection can be widespread following rains that splash spores onto plants and prolonged leaf wetness. Spore production increases with increasing duration of free moisture and occurs over a wide temperature range but is optimal between 58 to 72° F (15 to 22° C).

Spores landing on new, unexpanded leaves can infect those leaves without causing symptoms. The pathogen resides internally in the leaf tissue in a dormant state until the leaf is past maturity and begins to senesce and decline; at this point *B. cinerea* becomes active, further colonizes the dying tissues, and produces spores that can blow onto strawberry flowers and fruit. Mature, fully expanded strawberry leaves are not subject to infection. Spores land on strawberry flowers and cause the blossom blight phase of the disease. Such blighted blossoms develop lesions and either form abnormally shaped fruit or die. Once the diseased blossom tissues are dead, the gray mold fungus can sporulate and produce yet additional spores that result in multiple cycles of infection and disease.

In some cases, spores landing on strawberry flowers will germinate and begin to colonize the flowers but do not cause the brown lesion symptom; such flowers do not develop blossom blight. Instead, mycelium of *B. cinerea* will grow down the stamens and other flower tissues, reach the very small green receptacle, and remain there in a dormant (quiescent or latent) state. When the receptacle begins to expand and accumulate sugars and other nutrients, *Botrytis* can become active and cause a disease of the green fruit (Fig. 3). Lesion development in the fruit may be delayed and not visible until the fruit is at white, pink, or fully red stages. Ripe fruit that have injuries from physical abrasion, insect feeding, or other causes can also develop gray mold if spores land on the damaged areas. The gray mold fungus can sporulate on diseased fruit and produce more spores that can result in multiple cycles of infection and disease.

Post-harvest fruit losses can occur for various reasons: (1) dormant, quiescent infections become active late in fruit development so that apparently healthy but infected red fruit are harvested; (2) fruit having damaged areas, or fruit that are injured through the harvesting process, become contaminated with spores and can develop post-harvest gray mold; (3) healthy fruit in storage are placed in contact with diseased fruit and become infected due to “nesting.”



Figure 6. *Botrytis* as seen through a microscope at 400x magnification. *Botrytis* produces large numbers of single-celled spores that are readily spread via wind, splashing water, and physical contact.

Management

Fungicides: The careful and strategic use of fungicides remains the primary means of managing gray mold for conventional strawberry production. Because strawberries bloom over a period of many months, multiple applications are needed, throughout the season, using diverse products with different modes of action. Applications should be timed to maximize the protection of new and recently opened strawberry flowers. *Botrytis* is notorious for becoming resistant (insensitive) to fungicides because of its high genetic variability, profuse production of spores, and multiple cycles of spore production and disease development. The California strawberry production system may promote resistance because of the long growing season and the need for frequent applications made to each conventional crop. Fungicides with single-site modes of action are especially at risk for promoting resistance in *Botrytis*. Worldwide, resistant isolates of gray mold from strawberry have been confirmed for virtually all of the fungicide products that have single-site modes of action (Table 1). Especially problematic are isolates that are resistant to multiple modes of action. In the Carolinas, for example, *Botrytis* isolates from strawberry were found to be simultaneously resistant to fenhexamid, azoxystrobin, and boscalid.

Table 1. Fungicides used against *Botrytis* gray mold and reports of resistance

Chemical	Product	FRAC ₁ group	Resistant <i>B. cinerea</i> from strawberry outside of California	Resistant <i>B. cinerea</i> from strawberry in California
thiophanate-methyl	Topsin M	1	yes	yes
iprodione	Rovral	2	yes	no
boscalid	Endura	7	yes	no ₂
cyprodinil	Vanguard	9	yes	no
pyrimethanil	Scala	9	yes	no
pyraclostrobin	Cabrio	11	yes	no ₂
fludioxonil	Scholar	12	yes	no
fenhexamid	Elevate	17	yes	yes
captan	Captan	M4	yes	no
thiram	Thiram	M3	no	no
cyprodinil + fludioxonil	Switch	9 and 12	yes	yes
pyraclostrobin + boscalid	Pristine	11 and 7	yes	yes

¹ FRAC = Fungicide Resistance Action Committee.

² In California, resistant *B. cinerea* isolates have not been documented for the individual products pyraclostrobin or boscalid even though resistance has been confirmed for the combination product Pristine (pyraclostrobin + boscalid).

The most recent (see Mercier, et al.) examination of resistance for *B. cinerea* within California strawberry fields comes from a 2008 survey of coastal fields. Researchers found that over 90% of the 65 collected *B. cinerea* isolates from Oxnard and Watsonville were resistant to cyprodinil + fludioxonil (Switch), fenhexamid (Elevate), pyraclostrobin + boscalid (Pristine), and thiophanate-methyl (Topsin) (Table 1). This same survey found that a number of gray mold isolates were resistant to multiple fungicides and one isolate that was resistant to all four products.

The high proportion of resistance and the existence of multiple resistances argue for an integrated disease control program that would coordinate fungicide use at nurseries and fruit production operations. Repeated application of the same fungicides in nurseries and fruit production sites increases selection pressure and promotes resistance development. All fungicide programs should include rotations and tank mixes of products having different modes of action.

The Fungicide Resistance Action Committee (FRAC) provides a resistance group numbering system to categorize fungicides having the same mode of action (Table 1). Fungicides such as captan and thiram have significantly lower risk of resistance development in *B. cinerea* because these materials have multi-site activity against several metabolic pathways in the pathogen. One useful strategy is to combine (tank mix) two fungicides, where one of the tank mix partners is a multi-site active product.

For organic strawberry, effective fungicides are not available. Growers will need to implement, as much as feasible, IPM practices that include the cultural practices listed below. Before using any fungicides, check with your local Agricultural Commissioner's Office and consult product labels for current status of product registration, restrictions, and use information.

Sanitation: Sanitation measures, such as the removal of dead strawberry leaves and diseased fruit, appear to only slightly decrease gray mold incidence and cannot replace reliance on fungicide programs. Given the logistical difficulty and expense of such measures, these sanitation steps are not practical for most commercial growers.

Cultural practices: Spacing between plants could be increased to promote air movement and enhance drying of strawberry plants. This wider spacing may result in slight decreases in gray mold incidence but likely will not offset decreased yields due to reduced plant numbers per acre. Selecting cultivars that do not produce extensive leaf canopies, or the manipulation of transplant chilling hours to manage vigorous vegetative growth, could also help reduce gray mold. The use of drip irrigation, already a standard California practice, certainly is instrumental in reducing gray mold problems compared to sprinkler irrigation. While the California strawberry industry is characterized by outdoor plantings, in other regions strawberry is grown in protected culture inside of greenhouses or plastic tunnels. In such situations, gray mold can be reduced due to less free moisture and leaf wetness from dew and from exclusion of rain that would spread spores to flowers and fruit.

Host resistance: Currently there are no commercial strawberry cultivars resistant to gray mold. Among cultivars there appear to be slight variations in the degree of susceptibility to *B. cinerea*. However, such differences do not appear to be sufficiently different to alter the way the disease is managed in the field.

Harvest and post-harvest handling of fruit: Strawberry fruit are extremely sensitive to injury. Thus, physical handling should be minimized to reduce injury to fruit during harvesting and packing. Rapid cooling of harvested fruit to 32 to 37 F (0 to 3 C) is essential; a delay as short as one hour has been shown to result in increased postharvest losses to gray mold. Subsequent storage at these low temperatures is also necessary to retard gray mold and slow down fruit respiration.

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