

Charcoal Rot of Strawberry

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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

Beginning in 2005, strawberry growers in southern California reported an increasing problem with collapsing strawberry plants. The fungus *Macrophomina phaseolina* was consistently associated with these problems. The disease is called charcoal rot. Virtually all of the initial outbreaks were associated with fields that no longer were flat-fumigated with methyl bromide + chloropicrin that was shank injected under plastic tarp. Initially documented in Orange and Ventura counties, the disease in subsequent years was found in Santa Barbara and San Luis Obispo counties and then later in the central coast region (Monterey, Santa Cruz, and Santa Clara counties). Charcoal rot has also been found on strawberry in various other parts of California (San Diego, Alameda, Yolo, and Sacramento counties). Charcoal rot is economically important and over time can affect the majority of the strawberry plants in a field (Figure 1).

Symptoms

Initial symptoms of charcoal rot in strawberry usually occur after the plants are well established and begin to produce fruit: the older leaves wilt, turn gray green in color, and begin to dry up (Figure 2).



Figure 1. In severe cases, charcoal rot can affect large portions of a field.



Figure 2. Initial symptoms of charcoal rot consist of wilted leaves that become dull green or gray in color.

Plants will stop growing and appear to be stunted when compared to healthy plants. As disease progresses, virtually all of the foliage will collapse and dry up with the exception of the central, youngest leaves. Fruit production of infected plants may decrease prior to the development of disease symptoms. Warm weather and plant stress from insufficient irrigation, as well as other factors, will cause the disease to develop more rapidly and severely. Plants can eventually collapse and completely die (Figure 3). When internal tissues of plant crowns are examined, vascular and cortical tissues are dark brown to orange brown (Figure 4). Internal tissues of the main roots may also be discolored and dark brown in color.

Field diagnosis is made even more difficult due to the overlap of similar symptoms caused by other important soilborne pathogens. The internal crown discoloration is an important feature that distinguishes charcoal rot from *Verticillium* wilt, since collapsing strawberry plants infected with *Verticillium dahliae* often lack this symptom. However, *Fusarium* wilt of strawberry causes symptoms that are identical to those of charcoal rot. Accurate field diagnosis of collapsing plants is not possible because charcoal rot and *Fusarium* wilt look identical, both problems occur in the same counties, and any particular field could have both diseases. To identify which pathogen is causing strawberry plant collapse, affected plants must be tested by a plant pathology laboratory.



Figure 3. In advanced cases of charcoal rot, plants will completely collapse and die.



Figure 4. Strawberry crown tissue infected with *Macrophomina* will show a dark to orange brown discoloration.

Table 1 summarizes the similarities and differences among various strawberry pathogens causing plant collapse in California.

Table 1. Symptoms and factors associated with five major soilborne pathogens of strawberry.

Symptoms	<i>Macrophomina</i>	<i>Fusarium</i>	<i>Verticillium</i>	<i>Phytophthora</i>	<i>Colletotrichum</i>
Poor growth	Yes	Yes	Yes	Yes	Yes
Stunting	Yes	Yes	Yes	Yes	Yes
Wilting, mostly older leaves	Yes	Yes	Yes	No	No
Wilting, all leaves at once	No	No	No	Yes	Yes
Plant collapse	Yes	Yes	Yes	Yes	Yes
Discolored crowns	Yes	Yes	No	Yes	Yes
Soft, dark, rotted roots	No	No	No	Yes	Yes

Factors					
Associated with stress	Yes	Yes	Yes	No	No
Associated with excess water	No	No	No	Yes	No

Disease development

For charcoal rot of strawberry, the initial source of inoculum has not been determined. However, once *M. phaseolina* has infected strawberry plants, it produces small survival structures called microsclerotia (Figure 5); these structures allow the fungus to persist in the field for long periods of time. Microsclerotia in the soil germinate and infect strawberry roots. Having invaded the roots, the pathogen grows up into the crowns and petioles of the plant. Infected plants do not initially show symptoms and the plants appear to be healthy. However, once the infected plant begins to develop fruit (which is a form of physiological stress) and/or is subject to environmental stresses, the symptoms begin to develop: foliage drying and plant decline will appear. Environmental stresses may include the following: weather extremes, particularly high temperatures; water stress from insufficient irrigation or prolonged saturation in the root zone; poor soil conditions; pressure from pests such as mites. The pathogen colonizes the diseased strawberry plant and microsclerotia are produced in the tissues. The incorporation of such plants into the soil at the end of the season will introduce additional microsclerotia back into the already infested field.



Figure 5. Tiny, black microsclerotia enable the charcoal rot pathogen to survive in the soil. In this photograph, the width of the petri dish is 4.5 inches.

Because the microsclerotia of *M. phaseolina* are soilborne, any farming or harvesting practice that moves and spreads soil can potentially spread the pathogen. Soil preparation within an infested field prior to planting can readily move the fungus within the field, as evidenced by charcoal rot increasing with each successive planting. Infested soil adhering to equipment, tires, and vehicles can transport the pathogen to previously uninfested fields.

Macrophomina phaseolina is known to infect a wide range of host plants. In the case of *M. phaseolina* that infects strawberry in California, however, the extent of its host range is still not clear. Preliminary experiments have failed to show that strawberry isolates can infect known, non-strawberry hosts. In addition, there are examples where a known *Macrophomina*-host was planted in an infested field after the diseased strawberry crop was disked under. This second crop did not show any symptoms of charcoal rot. Future studies will hopefully answer questions about the host range of this pathogen. In contrast, the Fusarium wilt pathogen clearly is host-specific to only strawberry.

Management

The overall strategy for managing this disease depends on preventative measures. Once the strawberry crop is planted, there are very few options if charcoal rot starts to occur.

1. **Avoid planting into infested fields.** Plant strawberries into fields that do not have the pathogen and do not have a history of charcoal rot.
2. **Rotate crops.** Over-planting with strawberry is a practice that maintains or increases the soil population of this and other soilborne pathogens. Therefore, avoid planting strawberries in successive seasons by rotating to other crops. Broccoli may be particularly useful as a rotation crop due to the suppressive effect that broccoli crop residues have on a number of soilborne pathogens.
3. **Apply preplant fumigants.** The traditional methyl bromide + chloropicrin fumigation applied under tarp by broadcast fumigation is the most effective treatment. Fumigation will be most effective when crop residue is fully decomposed. Alternative fumigants are effective but to a lesser extent. It appears that alternative fumigants applied to raised beds are not effective in controlling *Macrophomina*, especially on the edges of the treated beds and at depths greater than 12 inches away from the drip lines that deliver the fumigants. Increasing the number of drip lines per bed (e.g., from two to three) will result in better distribution of fumigants and more complete treatment of the soil.
4. **Plant strawberry cultivars that have some tolerance to *Macrophomina*.** Truly resistant strawberry cultivars are not yet available for charcoal rot management. However, some strawberry cultivars show some tolerance to this pathogen and may not develop disease as severely as more susceptible ones. For example, while cvs. Chandler and Seascape are not widely planted anymore, these two cultivars will not collapse as readily when infected with *Macrophomina*.
5. **Plant strawberry plants that are pathogen-free.** Presently there is no evidence that transplants harbor *M. phaseolina*, but this possibility cannot be excluded with certainty. For managing charcoal rot, growers should continue to use high quality transplants that are not already infected with *M. phaseolina*.
6. **Avoid planting into buffer zones.** Field buffer zones, which by regulation will not be treated with any pre-plant fumigant or chemical, will certainly harbor soilborne inoculum of *Macrophomina*. Growers would be advised to not plant strawberries in such zones if previous crops were severely affected by charcoal rot.

7. **Avoid bringing *Macrophomina* into fields.** Microsclerotia of *M. phaseolina* are found in soil. Therefore, as much as possible, prevent the movement of infested soil and mud into fields by washing equipment and vehicles, limiting vehicle access to fields, and other measures. Complete soil preparation steps in uninfested fields before moving to known infested fields and areas.
8. **Miscellaneous cultural practices.** (A) As much as possible, reduce stress to the crop. *M. phaseolina* is a stress-dependent pathogen; if the crop is subject to stress, then disease symptoms will be more severe. Reduce stress by planting into well-prepared beds, irrigating appropriately, and managing pests, such as mites. Plants along the edge of the bed may be more prone to collapse due to drying, increased soil temperatures, or other factors associated with this location in the bed. (B) There are indications that in the case of strawberries affected with Verticillium wilt, large pieces of strawberry crowns likely harbor high numbers of microsclerotia from this pathogen. Removing or shredding and drying *Verticillium*-infected crowns prior to disking the field may reduce inoculum levels in the soil. Therefore, a similar strategy might also reduce inoculum of the charcoal rot pathogen. Any practice that results in more complete decomposition of plant residue should make fumigation more effective, too.
9. **Alternative approaches.** A number of approaches are being researched and practiced to provide additional options for dealing with soilborne pathogens such as *M. phaseolina*. Some of these methods show promise while others appear less effective or feasible. In most cases, these approaches require particular soil or environmental conditions to be effective and do not work in all situations or are not possible in all production fields. Some examples are the following: anaerobic soil disinfestation, biofumigation (e.g., incorporating broccoli crop residues or mustard seed meal), biological control, soil solarization, and steam treatment of soil.

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