MAJOR STRAWBERRY DISEASES

Gray Mold or Botrytis Rot

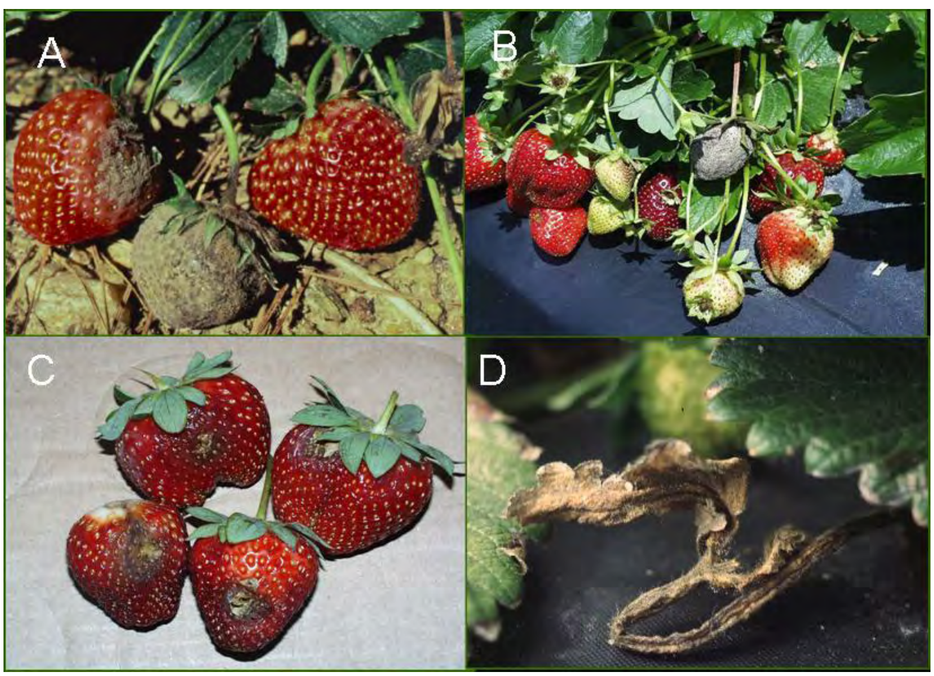
Gray mold is a serious disease in all strawberry production areas and is the primary disease of concern in most years. The disease is a problem not only in the field, but also during storage, transit, and market of strawberries, due to onset of severe rot as the fruits begin to ripen. Other parts infected by the fungus include leaves, crown, petals, flower stalks, and fruit caps. Crown rot is discussed elsewhere. Disease is most severe during bloom and harvest in seasons with lengthy periods of cloud and rain.

Gray Mold; Botrytis Rot (*Botrytis cinerea* (de Bary) Whetzel)

Symptoms and Signs

Gray mold may be prevalent during all stages of strawberry fruit development. Infected leaves and flowers turn brown and may die. Light brown lesions usually develop on the stem end of the fruit due to flower infections but may also occur on the sides of fruit where soil, standing water, or infected berries or flower petals are in contact (Figure 1). Infected berries may remain firm, yet become covered with gray spores and mycelium, giving the fruit a velvety gray appearance. High humidity favors mycelial formation that is visible as a white cottony mass. On undeveloped fruit, lesions may develop slowly and fruit may become mis-shapened and die before maturity. Fruit that are completely rotted become dry, tough and mummified.

Figure 1: Gray mold symptoms: a) on fruit in a matted row production system; b) on fruit in a plasticulture production system; c) on fruit where senescent flower petals fell allowing the pathogen to directly penetrate fruit; d) on senescent tissue.



Disease cycle

Botrytis primarily enters the field on transplant foliage. The fungus can live in the green tissue but be latent, or dormant, and not cause symptoms. Botrytis can affect many different crops and therefore weeds surrounding a field could be an important source of the pathogen. The pathogen can also produce dark hardened structures called sclerotia and these can persist in soils for years. However, in our recent experiments conducted in eastern North Carolina, we found no signs of *Botrytis* on surrounding vegetation, and found no indication of sclerotia (the overwintering form of *Botrytis*) in the soil, suggesting that those sources may be of limited importance in the spread of disease. As the infected strawberry leaf begins to die, the pathogen goes into an active stage, colonizing the leaf and obtaining its nutrients from the dead tissue (Figure 2). Spores then form and, once environmental conditions are appropriate (between 65-75 F and damp or rainy weather), they are dispersed by water splash and/or wind onto newly emerging leaves or blossoms. Immature fruits become infected primarily through blossom infections. Once the berries begin to ripen, the fungus is able to colonize them and sporulate, producing the mold often seen in the field.

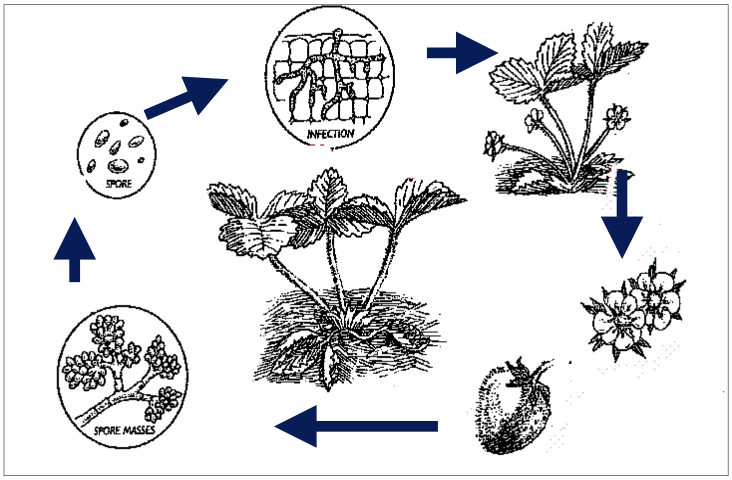


Figure 2: Infection cycle of B. cinerea in strawberry plantings from Cooley et al. 1996.

Factors of plant growth that are most important for disease development in annual planting systems:

1. Leaf senescence - Death of transplant foliage results in the production of spores from the initial inoculum introduced at planting. *Botrytis* will produce its spores on the dead leaf tissue and infect the leaves emerging during this time. Those newly infected leaves may then senesce two to three months later, during primary flower development (Figure 3).
2. Leaf emergence - Newly emerging leaves are extremely susceptible to infection. Upon infection in the fall, leaves will appear healthy until senescence occurs in the spring and the secondary inoculum is released.
3. Floral development - Release of secondary inoculum results in the infection of flowers and subsequent infection of the fruit. Rarely are the fruit themselves infected by an airborne spore, rather, *Botrytis* will stay dormant in the developing flower/fruit until factors such as increased ethylene production (ripening) and high humidity/rainfall allow for growth of the fungus.

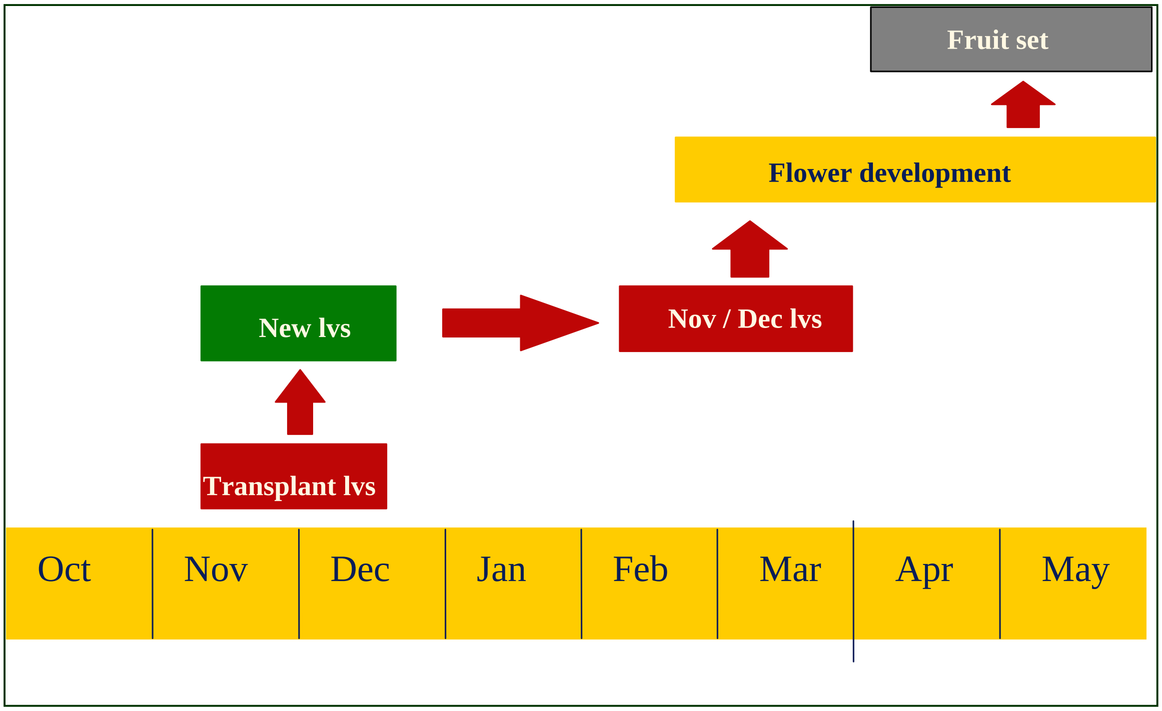


Figure 3: Proposed mechanism by which Botrytis is introduced on transplant leaves in October that subsequently die around November 15 to December 15. These dead leaves sporulate producing spores that infect newly emerging leaves. These November-December leaves die around late February to early March releasing spores as flowers are developing. The pathogen colonizes he flowers and subsequently enters the fruit to cause typical field symptoms of fruit rot.

Control

1. USE DISEASE-FREE PLANTS.

B. cinerea is commonly associated with transplant leaves and two years of research has demonstrated that there are no differences due to plant source or variety. Currently, it is not possible to obtain disease free plants. However, plug production practices may favor high populations of latent infections or crown rot problems (addressed elsewhere). Likewise, excess use of certain fungicides during the propagating phase results in resistant populations and poor control with these fungicides in fruit production fields.

2. MONITOR AND MANAGE

Excess nitrogen has been shown to increase fruit rot when weather conditions are favorable. To avoid over-fertilization, base fertilizer programs on leaf tissue nutrient analysis reports (see leaf sampling). Research has demonstrated increasing nitrogen levels beyond an optimum level does not increase yield but does increase fruit rot incidence.

Allow adequate spacing between plants to improve airflow in the canopy. However, manage plant spacing for optimum yields rather than to manage disease. Planting in raised beds improves drainage and also increases airflow, resulting in lower disease levels. Plastic mulch helps keep down rain splash, plant and soil-surface contact, weeds that may harbor *Botrytis* inoculum, and reduces moisture within the canopy. Drip irrigation provides a direct source of water and eliminates excess moisture from fruit and leaves. Removal of senescing tissue from the field may be helpful in the fall, but is likely of most benefit in the early spring, just prior to bloom, to help lower inoculum levels. An economic analysis has not been performed on the benefit of sanitation. In studies where sanitation was conducted, yields tended to be highest and benefits most pronounced if fungicides are not used (e.g. organic production systems). Harvested fruit should be monitored for disease, and infected berries removed. Rapid removal of field heat and keeping fruit at around 34 F and increasing carbon dioxide levels during shipping (12-15 % concentration in gastight storage bags) when harvested will help keep *B. cinerea* down.

3. CHEMICAL CONTROL

Fungicides play a major role in the management of this disease. Fungicide applications are critical in problem fields during early and full bloom. These fungicides are targeted to limit flower infection that leads to fruit infection, and should limit the need for late season applications to the fruit. A few well-timed sprays are less costly and more effective in controlling gray mold than frequent fungicide applications through harvest.

A detailed fungicide schedule is included elsewhere (see www.smallfruits.org).

Botrytis cinerea has developed resistance to MBC-generating compounds (e.g. thiophanate-methyl = Topsin-M) and dicarboximides (iprodione = Rovral). Therefore, alternating between chemistries or using tank mixes is highly recommended. Topsin-M is best used in combination with a protectant fungicide such as captan. Topsin-M will be of most benefit in bare root plantings and during the bloom phase.

Elevate is a protective fungicide with good efficacy against *Botrytis*, and should prove to be a useful tool where resistance to other fungicides has become a problem. It can be used alone or in combination with other fungicides as a tank mix and can be used up to and including the day of harvest. Elevate limits penetration of the *Botrytis* pathogen into the plant by limiting spore germination, germ tube elongation and mycelial growth. Elevate should not be used for more than two consecutive sprays to avoid selection of resistant fungal populations, according to standard practices for resistance management.

Switch has 2 types of fungicides (cyprodinil = systemic + fludioxanil = protectant) and is also a superior botryticide but has a wide range of activity. It is best rotated in with other fungicides. Based on some of our data, Switch appears to reduce post-harvest fruit rot incidence also.

Pristine is also a combination product (QoI chemistry + boscalid). The boscalid component has excellent Botrytis activity. The QoI component is the same component as Cabrio (pyraclostrobin) and thus care must be taken when developing a fungicide schedule (see notes on anthracnose and the fungicide schedule elsewhere).

Other new chemistries are currently being evaluated, and should provide efficient alternatives to traditional fungicide programs.

For organic growers, vigilantly manage plant growth as described above and incorporate plant sanitation by removing dead and dying leaves just prior to bloom. Some experience is available on the use of compost teas, biological control products, and other products (biological control products) and can be discussed further with a strawberry specialist. Harvest fruit in a timely manner and remove field heat ASAP to ensure fruit is cooled down prior to shipping or selling.

4. BIOLOGICAL CONTROL

Antagonistic fungi such as *Trichoderma harzianium* Rifai and *Gliocladium roseum* Bainier have been used in Europe and Brazil as alternatives to fungicides. Efficacy trials in the USA provide limited information on effective biological controls for plasticulture production systems. In the northeastern matted row production region, bees have been used efficiently to deliver beneficial fungi to flowers resulting in reduced gray mold incience.

Remember, *Botrytis* is in the field all season long. Don't wait until peak bloom or fruit set to begin control practices. Plan ahead and design your management program to inhibit disease progression at critical points in the season.

Causal Organism [on separate page using hot links with detailed images for the diagnostician]
Botrytis cinerea (anamorphic state *Botryotinia fuckeliana* (deBary) Whetzel) hyphae are branched, septate, hyaline. Conidiophores are long (2-5 mm), dark brown, branched primarily near the apex, determinate with swollen terminal cells that form ampullae. Conidia (8-14 x 6-9 μm) are one-celled, multinucleate, obovoid, colorless or pale brown, and are born on denticles protruding from each ampulla giving it a grapelike cluster appearance. In mass, conidia appear gray to grayish-brown. Sclerotia are black, irregular in shape, and can be up to 5 mm long.

ANTHRACNOSE OF STRAWBERRIES

Anthracnose is an important disease of strawberry fruit, crowns, leaves, petioles and runners. Three related species of the fungus *Colletotrichum*, including *C. acutatum, C. gloeosporioides*, and *C. fragariae* can be associated with strawberry plants. Disease control is difficult when environmental conditions are favorable and if the pathogen is present, and the disease can be especially destructive to California strawberry cultivars when grown on black plastic.

Colletotrichum acutatum is more commonly associated with fruit rot, but has also been associated with crown rot and problems in plug production systems. *Colletotrichum gloeosporioides* tends to be associated with the crown rot phase of anthracnose. *Colletotrichum fragariae* is the primary organism causing crown rot and is not commonly a problem on fruit. It has not been isolated as a common pathogen in North Carolina since 1986. *Colletotrichum dematium* occasionally causes strawberry fruit rot, but is not considered to be a major cause of anthracnose diseases on strawberries.

Symptoms and Signs

Anthracnose **Fruit Rot or Black Spot** (*C. acutatum* and *C. gloeosporioides)*

Figure 1: Anthracnose fruit rot. The ripe rot is typical of most fields in the Southeastern region with sunken circular lesions containing masses of spores.

Anthracnose fruit rot appears as brown to black, water-soaked spots on green and ripe fruit. Firm, sunken lesions can develop over time. Pink, salmon, or orange-colored masses of spores may form in the lesion under humid conditions (Figure 1). Under dry conditions, the entire fruit may dry up and become mummified. Buds, pedicels, peduncles, and flowers of most cultivars are susceptible to anthracnose. Flowers may also die and dry out. If infection occurs shortly after pollination, the developing fruit remains small, hard, and is mis-shapened. Infected tissue placed in an incubation chamber will sporulate within 24 hours. Symptoms can be confused with Alternaria fruit rot, Phomopsis frit rot, Rhizoctonia dry rot, or hail damage but the combination of signs (spores, sterile setae etc) and symptoms is diagnostic for this disease.

Anthracnose Crown Rot (Colletotrichum gloeosporioides, C. acutatum, and C. fragariae)

Figure 2: a) Typical "marbled" appearance of infected crown caused by *C. gloeosporioides, or C. fragaria*. b) Brown discoloration in the top of the crown caused by *C. acutatum* infection initiated during the plug production phase.

Initial symptoms of **Anthracnose Crown Rot** are red streaks on petioles and runners. These mature into sunken, dark, and firm lesions. Advanced lesions may girdle the petioles and runners, causing the leaf or daughter plant to wither and die. Pink conidial masses develop under humid conditions and are mostly seen in the center of the lesion. Setae may be present depending on the species involved. The lesions may also grow down into the crown and cause crown rot. Initially plants wilt in the heat of the day, which is often over-looked as drought or heat stress. In advanced infection, the entire plant will die. Cutting the crown lengthwise reveals white and reddish brown streaks, creating a marbled effect, or a firm rot (Figure 2). The fungus can be isolated from this discolored region by placing pieces of infected tissue onto potato dextrose agar. *C. acutatum* can also cause a bud rot, where infected buds turn dark brown to black and develop a firm rot. Within a crown a single bud may die and the plant will continue to thrive, or the entire crown may become infected, wilt, and collapse. Pink conidial masses usually form on the rotted bud. We have isolated *C. acutatum* from strawberry roots and such infections have been documented to cause a generalized stunting.

Disease Cycle

The primary source of anthracnose inoculum enters the fields on strawberry transplants (figure 3). *C. acutatum* has been reported to survive in soil and plant debris for 9 months, and *C. acutatum* and *C. gloeosporioides* may infect weeds growing alongside of the field. However, in North Carolina, field experience suggests overwintered (and oversummered) inoculum is not important and infected strawberry transplants are the primary source of inoculum. Conidia are produced in abundance on petioles, runners, and fruit and are dispersed through rain-splash, especially wind-driven rain. Movement of machinery and workers through the field also may contribute to inoculum spread. Warm, humid conditions are optimal for this disease, thus cultural practices that encourage aeration and rapid drying of fruit should be used. Straw mulches may help to reduce the dispersal of spores in splashing water, but plastic mulches provide a springboard for droplets, thus encouraging the spread of disease. Overhead irrigation can also contribute to disease spread.

Crown rotting species may survive cooler temperatures by remaining latent within the crown of the plant until temperatures warm up. In annual plasticulture systems, early establishment of disease in the fall may result in wilting or death of transplants. In spring plantings, wilted plants are a source of secondary inoculum that may spread to epidemic proportions through splash dispersal.

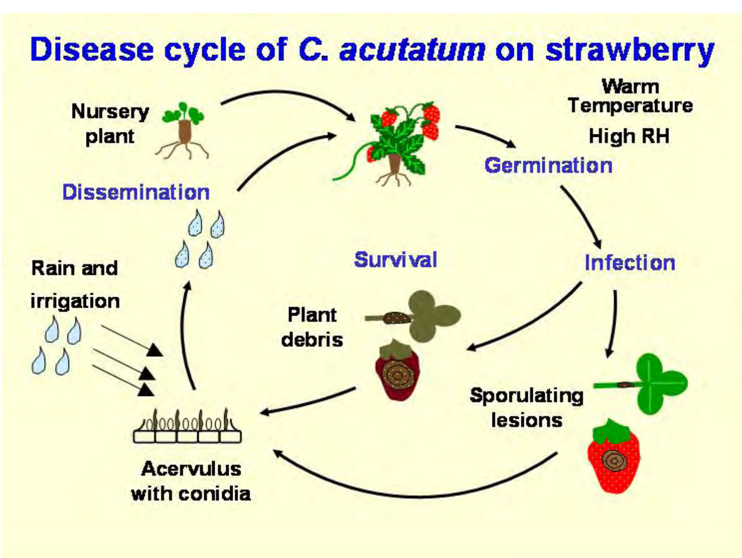


Figure 3: Life cycle of *Colletotrichum acutatum*. Composed by Leonor Leandro.

Control

1. USE DISEASE-FREE PLANTS

Rarely does anthracnose recur year after year on the same farm. The disease has been associated with asymptomatic plants imported from transplant supply nurseries. Thus, the use of disease-free plants is the most important management strategy for controlling this disease. Currently there is no rapid detection method for diagnosing anthracnose-infected transplants prior to planting. Plants have reduced risk of disease if they have been micropropagated and then entered into a strict plant certification program. North Carolina State University and the North Carolina Crop improvement have implemented such a program including strict guidelines for certification. Similar standards by other nurseries or suppliers will help reduce the risk of anthracnose.

Resistant cultivars are available and breeding efforts have shown promise. For example, Sweet Charlie is less susceptible to the fruit rot phase than other cultivars commonly grown on plastic.

2. MONITOR AND MANAGE

Periodic scouting of a field, especially during warm and wet weather, will enable early detection of anthracnose. If the problem seems to be associated with hot spots in the field, remove and destroy (bury or burn) infected plants and surrounding plants (5 to 10 foot radius). Killing the plants with herbicide will initiate spore production by the pathogen, and if these plants are not removed the problem will be aggravated.

Nitrogen levels should be kept at the required level, since high nitrogen levels in the soil favor fungal development. Keep foliage dry and reduce water splash by use of drip irrigation to help lower conidial dispersal and spread of the pathogen.

- Avoid excess overhead irrigation (e.g. for evaporative cooling) and do not over water or over fertilize.
- Always pick the infested area last and do not let personnel or equipment move from an infested area to clean areas in order to limit spread of the pathogen.
- Do not work plants when wet.
- Although the economics are not available, it may be practical to pick and remove infected berries out of the field in order to reduce the amount of inoculum. However, be aware that this pathogen colonizes leaves and other green tissue without showing symptoms. Therefore, if the pathogen is on the fruit, it will also be on the plant tissue and it will be impossible to remove entirely. Removing infected fruit should help to reduce disease pressure.

3. CHEMICAL CONTROL

See the recommended fungicide schedules elsewhere (www.smallfruits.org).

It is currently suggested that you save the strobilurin (now called QoI) fungicides (Abound, Cabrio, and Pristine) for use in controlling anthracnose ripe fruit rot during optimum disease conditions. Captan or Thiram should help to suppress anthracnose when utilized in botrytis or other disease control applications, but the QoI materials (Cabrio, Pristine, Abound) are currently the most efficacious materials for control of anthracnose. Some of these QoI materials may have activity against multiple pathogens other than anthracnose, but unless anthracnose occurs in conjunction with these other diseases of concern, it is suggested that the QoIs not be used. With only 5 total applications of these materials per crop, it is an imperative that they be utilized effectively. Also, resistance management is extremely important with the QoIs; make sure to follow all resistance management guidelines.

For C. gloeosporioides, if there is no other option than using plants with known minor infestation, fungicide dip the fresh-dug plants with Switch @ 5-8 oz/100 gal water or dip plants in Abound @ 5-8 fl. oz/100 gal water. Dip plants for 2-5 minutes and plant as soon as possible after dipping. Follow all label directions carefully. If possible, minimize irrigation from overhead sprinklers. Our research results indicated that significant reduction of plant mortality and increase in yield can be obtained by dipping infested plants in Switch before planting.

4. ROTATION

Rotation out of strawberries for 2 or 3 years will help to rid the field of inoculum from infected plant tissues or infested debris in the soil. However, in North Carolina, the experience has been that anthracnose does not commonly reappear a second year in a field unless the disease is re-introduced on contaminated plants or if plants from the previous year persist on the farm over summer.

ADVANCED information on Anthracnose:

Colletotrichum acutatum J. H. Simonds is more commonly associated with fruit rot, but has also been associated with crown rot. Conidia form rose, salmon pink, or orange masses and are produced in an acervulus. Setae are rarely observed. Conidial (8.5-16.5 x 2.5-4 um) ends are tapered. When setae do form (generally on strawberry leaf agar), they are much smaller (5.2 x 3.2 um) than setae produced by *C. fragariae*. Colonies are pink, orange, lavender, or white and turn gray with age. This species grows slower on PDA than either *C. fragariae* or *C. gloeosporioides*.

Colletotrichum gloeosporioides (Penz.) Penz. and Sacc. tends to be associated with the crown rot phase of anthracnose but can also cause fruit rot. It has frequently been isolated in nurseries. This species commonly forms the teleomorph. Conidial masses are pale pink, whitish, or translucent. Conidia are more rounded at the base that *C. fragariae*.

Colletotrichum fragariae A. N. Brooks is the primary organism causing crown rot and is not commonly a problem on fruit. It has not been isolated as a common pathogen in North Carolina since 1986. Lesions form on petioles, runners, and leaves. Conidia (12.5-16.5 x 4.5-5 μm) are cylindrical, straight, and rounded at the apex and taper to a point at the base. They are produced in acervuli or on aerial hyphae. Setae (50-200 x 3.5-4.5 μm) are usually present and are 3-5 septate and fasciculated. On potato dextrose agar (PDA), colonies are olive, gray or black with dark gray or olive reverse. Isolates have not been reported to form a teleomorph.

Colletotrichum dematium has sickle-shaped conidia (18-26 x 2-3 μm) and are produced in acervuli with abundant setae. Colonies on PDA are gray with a white margin. This species occasionally causes strawberry fruit rot, but is not considered to be a major cause of anthracnose diseases on strawberries.

Phytophthora Crown Rot

Strawberry infection by *Phythophthora cactorum* is aggravated on poorly drained, over-irrigated soils, or during long periods of rain in warm climates. Symptoms of disease are enhanced during periods of high water need, such as after transplants are set, during hot dry weather, or as the fruit load increases.

Phytophthora Crown Rot (*Phytophthora cactorum* (Lebert and Cohn) J. Schrot.)

Symptoms

Stunting of plants or wilting of young leaves are the first symptoms and may appear at any time during the season. Current plant collapse problems are associated with fruit production and the warm weather. The pathogen infects the crown and causes a uniform brown discoloration (Figure 1) and plants will die. The dark brown discoloration may appear at the base or middle of the crown. In many cases, the brown discoloration in the crown is associated with roots that are infected and by which the pathogen enters the crown. This crown infection results in symptoms similar to severe drought stress. Leaf margins begin to turn brown and entire leaves will die (Figure 2). Plants may break freely at the upper part of the crown when pulled. Roots often are discolored brown also. In contrast, tissue infected by the anthracnose pathogen takes on a darker cinnamon color, is more firm, and often has a “marbled” appearance. In diagnostic clinics, root surface scrapings will (often) reveal *P. cactorum* oospores in the tissue (Figure 3) using a compound microscope.

Disease Cycle

Infection is favored by wet conditions. The primary inoculum sources include oospores in the soil and infected transplants. Most epidemics in the southeastern region to date have been associated with plant problems and the importance of soil-borne inoculum is not well documented. Disease expression is influenced by time of planting and environmental conditions. Plantings established in fall may have wilted plants soon after planting but it is possible the disease will not be expressed until the following spring after the pathogen has resumed activity.

Figure 1: Left) Internal crown discoloration due to Phytophthora infection. Right) Mature planting near bloom showing empty spaces where infected plants died. Neighboring plants did not appear to be infected.

Figure 2: Left) Part of the plant has wilt symptoms due to Phytophthora infection. Right) Leaves show symptoms of drought stress beginning at the leaf margins.

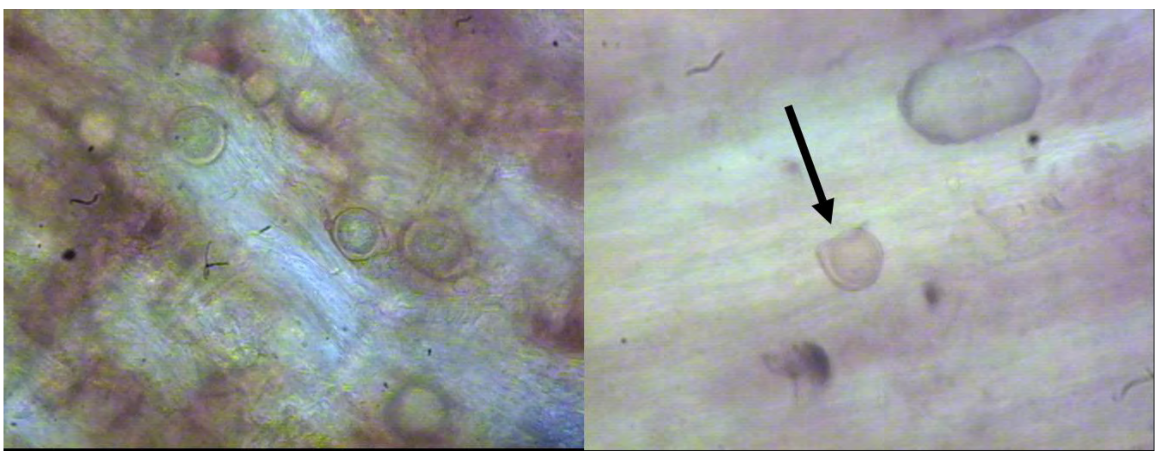


Figure 3: Clinics or labs with microscopes can take root tissue and directly observe oospores in infected tissue to achieve a rapid diagnosis. We also culture on Phytophthora selective media to confirm the problem. These oospores can escape into the soil and potentially persist for years.

Control

1. SITE SELECTION AND PREPARATION
   Choose a site with adequate soil drainage and avoid fields with a history of disease. Plant in raised beds, not low wet spots, and rip fields during preparation. Soil fumigation may help to reduce inoculum.
2. USE DISEASE FREE PLANTS.
   Use healthy plants, although symptoms may not be apparent at the time of field setting.

3. MONITOR AND MANAGE
   Use proper irrigation practices; do not overwater as inoculum is spread by runoff.
4. CHEMICAL CONTROL

Phytophthora cactorum, has become a recurrent, though not common problem in our industry. Under conditions of heavy rains experienced by plant suppliers and/or wet soil conditions in fall, growers should consider the use of Ridomil Gold in their planting beds. The label allows for the "first application after transplanting". It should not be used on plug plants prior to planting, as a dip, or in the transplant solution as these are not labeled uses and can cause plant stunting – in our experience. Use 1 pt per treated acre (NOTE: Only half of an acre of strawberries is actually under plastic meaning 1 acre of land has 0.5 acres of treated area). It is best to apply Ridomil Gold after the time of excess watering and when the plants have taken a root-hold – approximately 2 weeks after transplanting. Ridomil Gold is best applied through the drip irrigation system. Ridomil Gold is much more effective than the phosphorous acid generators (e.g. Aliette, Prophyt, Phostrol etc) for managing Phytophthora. The phosphorous acid generators are helpful in specific circumstances where Ridomil cannot be applied or when strawberry roots are severely damaged and a foliar spray of a product is the best option.

In fields with severe and widespread stunting, the use of Aliette or ProPhyt (phosphorous acid generators) may prove beneficial as a foliar spray. Such plants may have poor root systems and will not take up Ridomil efficiently. Aliette and ProPhyt will be absorbed into the leaves and move down the plant to the crown and roots. Excess use of Ridomil will lead to pathogen populations resistant to the chemical.

In the spring, additional applications may be beneficial. We generally recommend an application during the period of active new root growth (early March).

Our experience with Phytophthora crown rot of pepper has shown that there is benefit when Ridomil Gold is applied as a broadcast treatment prior to forming the beds. Alternatively, Ridomil Gold could be drip applied prior to field setting transplants. This apparently ensures Ridomil is available to the plants when they are field set. It can be difficult to get adequate concentrations of Ridomil Gold to the plants relying on drip irrigation only in the fall. These thoughts are consistent with the label but have not been adequately researched in strawberry production systems.

About The Use Of Ridomil Gold During The Harvest Season. Growers ask about the use of Ridomil Gold during harvest and the waiting period required after treatment. The label offers no clear guidelines and I pursued this with the company. There is no waiting period for Ridomil when applied through the soil as recommended. This may seem concerning since Ridomil Gold is a systemic fungicide and may pose a health concern. However, the answer probably relates to the anatomy of the strawberry leaves and fruit. Ridomil moves through the apoplastic tissue (dead tissue and cells like the xylem or water conducting tissue). Therefore, soil applied Ridomil Gold typically follows the transpiration stream of the water and will accumulate in the leaves and other tissue that have stomates and therefore transpire a lot of water. However, the strawberry fruit does not have stomates and the fruit does not transpire large volumes of water.

Rather, the fruit is a sink accumulating sugars etc from the symplastic pathway (living cells such as the Phloem). Therefore, Ridomil Gold does not accumulate in the fruit reducing residue concerns. I was involved in a number of studies with Ridomil 15 years ago documenting this type of effect. Therefore, in fields where harvest has not reached a peck and plant vigour is good, benefit may be achieved with a Ridomil Gold application if *Phytophthora cactorum* has been diagnosed. Strawberry plants will continue to put out adventitious roots and (in previous work I've done with red steele at least) there is a curative effect. Dr. Fernandez and I have had students who monitored root growth and plant anatomy and after this peek growth period the plant seems to go "downhill" and there is likely little benefit to the use of Ridomil Gold to limit disease problems. That is why in our previous recommendations we emphasized the use of Ridomil Gold as the spring growth season really initiates.

PLEASE NOTE:
Recommendations of specific chemicals are based upon information on the manufacturer’s label and performance in a limited number of trials. Because environmental conditions and methods of application by growers may vary widely, performance of the chemical will not always conform to the safety and pest control standards indicated by experimental data.

Recommendations for the use of chemicals are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products or services in this publication does not imply endorsement by the North Carolina Cooperative Extension Service nor discrimination against similar products or services not mentioned. Individuals who use chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage and examine current product label before applying any chemical. For assistance, contact your county North Carolina Cooperative Extension Service agent.

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Alternatively, if roots are badly damaged, plants have responded well to an Aliette application. These products are not needed if Phytophthora is not present.

Bacterial Angular Leaf Spot

Angular Leaf Spot disease of strawberry, caused by the bacterium *Xanthomonas fragariae,* is often confused with common leaf spot and leaf scorch diseases. Once infection is established, little can be done until the wet cool conditions subside.

Bacterial Angular Leaf Spot (*Xanthomonas fragariae*)

Symptoms and Signs
Water-soaked lesions first appear on the lower surface of the leaf, becoming angular as they enlarge and usually delineated by veins (Figure A). When conditions are very moist, lesions may exude a viscous yellow substance that is actually a mass of bacteria. Upon drying, a characteristic white film is left on the leaf surface. In time, lesions will also be visible on the upper leaf surface as irregular, reddish brown spots that may be surrounded by a yellow halo. These symptoms are difficult to distinguish from common leaf spot and leaf scorch. One identifying characteristic is the translucent nature of lesions when leaves are held up to a bright light; looking from the backside, light will pass through the angular lesions. Entire leaves and major veins may become infected, giving the leaves a ragged appearance (Figure G). Berry caps may become infected, darkened, have angular lesions and are unappealing (Figure C). Vascular infection and wilting by *X. fragariae* may lead to plant death, but this is not as common as leaf spot. This systemic infection may be confused with wilt of anthracnose or Phytophthora crown rot; however, crown tissue infected by *X. fragariae* does not become discolored. Infected material will typically ooze bacterial cells when dissected and viewed under a compound microscope (Figure F).

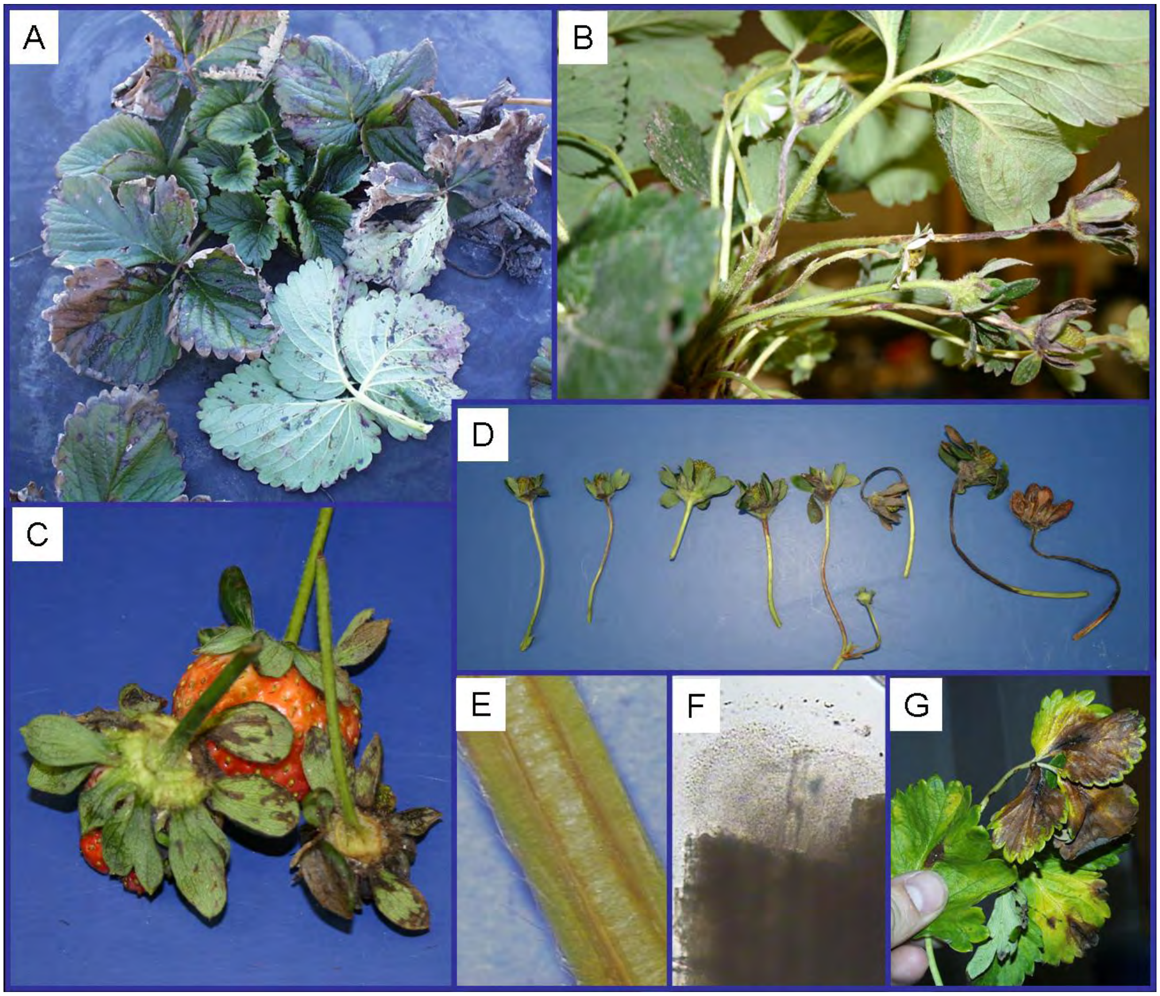

Figure: A) Plant severely infected by *Xanthomonas fragariae* and overturned leaf showing angular leaf spots between veins where bacteria have colonized the tissue; B) A flower truss with symptoms of black discoloration on the calyx and peduncle; C) Angular lesions on the calyx of developing fruit; D) range of symptoms on the calyx and peduncles; E) brown discoloration in the xylem tissue due to systemic infection by the bacteria; F) Bacterial ooze from infected strawberry tissue that serves as a positive diagnosis for angular leaf spot (100x); G) Leaf showing a blight symptom associated with systemic infection by *X. fragariae*.

Disease Cycle

X. fragariae primarily enters the field via infected planting stock, and may persist in the field by overwintering or oversummering in infected plants and dead leaves. In the Southeast, problems have not persisted from one year to the next in annual plantings due to soil inoculum. The pathogen cannot survive freely in the soil, but can survive on transplants in cold storage for one year and on plant debris through long dry periods. Bacteria become active and are splash-dispersed to healthy leaves in wet weather or with irrigation water. *X. fragariae* favors low day (60F) and night temperatures (near freezing) and high relative humidity. Favorable conditions for disease development occur during transplant establishment and when frost protecting. Cool wet weather during flowering and fruit formation can cause loss of fruit (figure B & D) or lead to a discolored calyx – rendering the fruit unmarketable. Healthy plant tissues are more likely to become diseased than stressed tissues. In most cases, yield losses due to angular leaf spot are not common but may occur when severe systemic infection occurs. Losses can be substantial if a large portion of the fruit calyxes are infected and unsightly.

Control

1. SITE SELECTON

Choose a site with good air circulation and sun exposure to promote drying of foliage.

2. USE DISEASE-FREE PLANTS

Use certified plant material. Be aware that infected transplants may not exhibit signs of infection until exposed to a more favorable climate, such as exists in the southern states. Resistance to angular leaf spot exists in some genotypes, yet no commercially desirable cultivars contain high levels of resistance, especially for annual production systems.

3. MONITOR AND MANAGE

Control weeds to allow air to circulate freely around plants. Remove infected leaf debris by hand, raking or vacuuming. DO NOT remove infected debris if anthracnose is suspected to be present. Avoid using overhead irrigation if possible. Under serious disease conditions, ensure all strawberry debris is soil incorporated to optimize tissue break down. Rotation is not essential. A change in weather patterns from cool and wet to warm and drier results in disease decline.

4. CHEMICAL CONTROL

No bactericides are labeled for use nationally against angular leaf spot. Early application of registered copper materials prior to rapid growth may reduce disease, but fungicides are not very effective in managing angular leaf spot because the bacteria can reside within the plant tissue. Caution should be taken when using copper fungicides because accumulations can be phytotoxic. Angular (bacterial) leaf spot can be a serious problem during cool, wet conditions. Registered copper compounds provide some control of the peduncle and calyx infections. In fields with a known problem, apply copper fungicides when flowers and fruit are present and when cool wet weather is predicted. Repeat applications at 7 to 10 day intervals. Discontinue when phytotoxicity appears, usually after 4-5 applications.

PLEASE NOTE:
Recommendations of specific chemicals are based upon information on the manufacturer’s label and performance in a limited number of trials. Because environmental conditions and methods of application by growers may vary widely, performance of the chemical will not always conform to the safety and pest control standards indicated by experimental data.

Recommendations for the use of chemicals are included in this publication as a convenience to the reader. The use of brand names and any mention or listing of commercial products or services in this publication does not imply endorsement by the North Carolina Cooperative Extension Service nor discrimination against similar products or services not mentioned. Individuals who use chemicals are responsible for ensuring that the intended use complies with current regulations and conforms to the product label. Be sure to obtain current information about usage and examine current product label before applying any chemical. For assistance, contact your county North Carolina Cooperative Extension Service agent.