CALIFORNIA STRAWBERRY COMMISSION
A HEALTHY INDULGENCE

PRODUCTION GUIDELINES

VERTICILLIUM WILT OF STRAWBERRY

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Issue 1.1 July 2008

Introduction and significance

Verticillium wilt was a major problem for the California strawberry industry until the widespread adoption of preplant fumigation with methyl bromide and chloropicrin. Through regular use of soil fumigation, pathogen populations have been kept below damaging levels in most fruit production fields. However, the pathogen may still be present and can increase to damaging levels over time, if an effective fumigant is not used on a regular basis. Once established in a field, the pathogen population may increase with successive strawberry crops. In addition, the pathogen can be moved with soil, or normal farming operations may serve to distribute it within a field and move it to neighboring fields. Verticillium wilt can also be a problem at high elevation nurseries, where it can reduce productivity and potentially allow for movement of the pathogen to fruit production fields.

Figure 1. All five plants pictured here were transplanted into a fruit production field on the same date. Four plants were infected by Verticillium dahliae and became severely stunted. The healthy appearing plant was not infected.

Symptoms and diagnostic features

The development of Verticillium wilt can be strongly influenced by the timing of infection and cultivar susceptibility. Where infection occurs very early in the season and/or the affected cultivar is highly susceptible, plants may be severely stunted (Figure 1). Disease symptoms may be much slower to develop in less susceptible cultivars and where infection occurs later in the season. Late infections are typical of low inoculum levels, because the root system may develop extensively before it encounters the pathogen in soil. In these cases, plants often become quite large and may be indistinguishable from healthy plants through much of the season. Verticillium wilt may then cause limited dieback and some reduction in yield or may kill the affected plant entirely (Figures 2 and 3). Verticillium wilt does not cause visible damage to the root system and will not necessarily cause any internal discoloration in the crown of the plant.

Figure 2. One plant (middle) is showing dieback symptoms typical of Verticillium wilt. The others are healthy.

Life history of the causal agent

Verticillium wilt in strawberry is caused by the fungus *Verticillium dahliae,* which is found in agricultural soils throughout California. *Verticillium dahliae* produces structures known as microsclerotia that can survive relatively long periods in soil, where they remain dormant until a plant root grows nearby. In response to nutrients released by a growing root, microsclerotia will germinate and grow toward the root. Infections limited

to the cortex cause no visible damage to the root and many such infections may be sustained without any impact on yield. Verticillium wilt develops only after one or more cortical infections extend into the water conducting tissue (xylem).

Once in the xylem, the pathogen produces spores that can move upward with water being transported from the root to the shoot. This is termed a systemic infection and usually leads to development of symptoms. Once an infected plant dies, the pathogen can grow more extensively and produce microsclerotia within decomposing crop residue (Figures 4 and 5), adding to the population of the pathogen in soil. Microsclerotia can survive from one to several years in soil, depending on cropping patterns and other conditions.

Figure 3. Premature death of strawberry plants in June caused by Verticillium wilt in an unfumigated, experimental field.

The pathogen causing Verticillium wilt of strawberry is also capable of infecting other crops. In fact, *V. dahliae* will infect the roots of most plants, whether or not they are susceptible to Verticillium wilt. These infections are usually limited to formation of small cortical colonies in the root (i.e., they do not become systemic) and therefore produce few microsclerotia. Consequently, infections of this type probably do not make a significant contribution to the size of the pathogen population in soil. However, this mode of reproduction does help the pathogen to persist and, coupled with the longevity of microsclerotia, ensures that once a field is infested it is likely to remain so unless aggressive measures, such as fumigation, are taken to eradicate the pathogen.

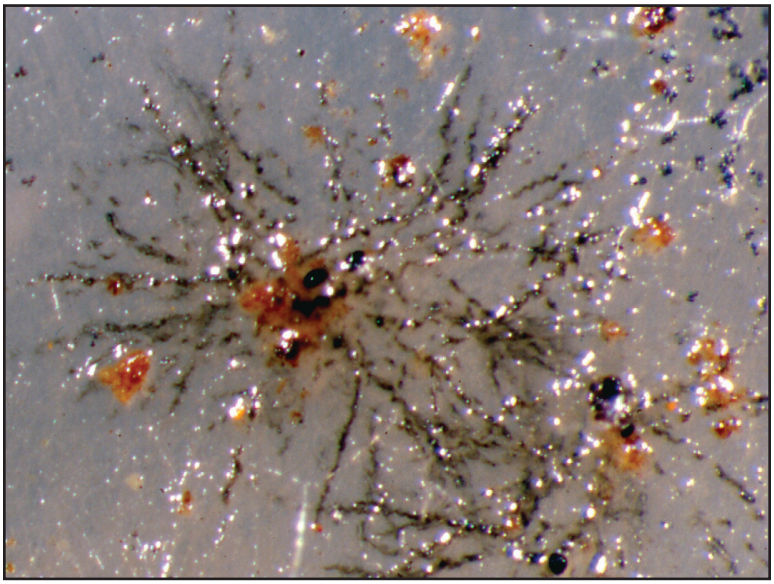

Figure 4. The small black structures are microsclerotia forming within decomposing strawberry petioles.

Strains of *V. dahliae* that cause disease on strawberry may also be pathogenic on other crops. Recent studies have shown that strains of *V. dahliae* from lettuce, strawberry and watermelon affect a similar range of crop hosts. For example, the lettuce strain was virulent towards artichoke, chili pepper, cotton, eggplant, lettuce, potato, strawberry, and watermelon; the strawberry strain was highly virulent on artichoke, cotton, eggplant, mint, lettuce, potato and watermelon; while the watermelon strain was virulent on artichoke, cotton, eggplant, lettuce, potato, strawberry and tomato. All these crops become systemically infected by *V. dahliae* and microsclerotia may form extensively within the residue of infected plants. As a result, strawberries following these crops may encounter very high levels of inoculum in the soil. This is a particular concern in production fields that are rotated with lettuce and at high elevation nurseries that are located in potato production areas. It should be noted that both lettuce and potatoes are much more tolerant of *V. dahliae* than strawberries. Therefore, one should not assume that the absence of symptoms on either crop indicates it would be safe to follow in the same field with strawberries.

Management

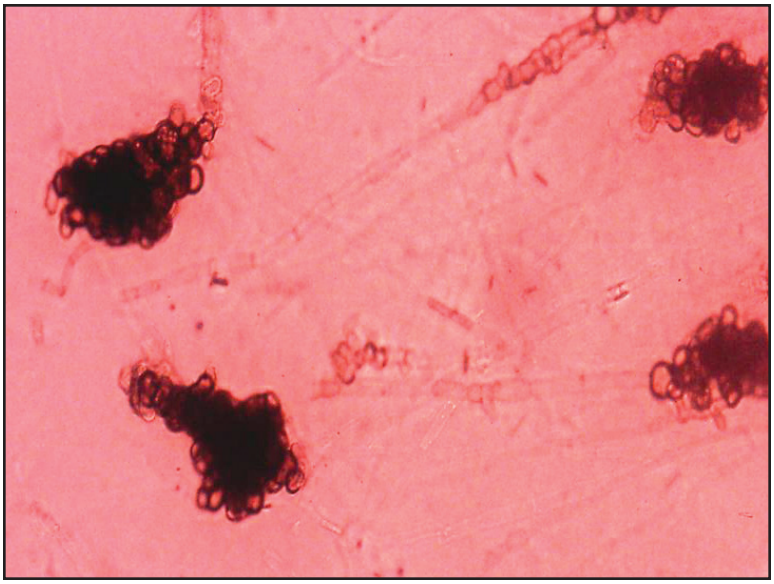

Figure 5. Individual microsclerotia from a strawberry strain of *V. dahliae* under a microscope magnified 400 times.

Verticillium wilt must be managed through prevention, because no efficacious therapeutic measures are available. This can be achieved by ensuring that damaging levels of the pathogen are not present in the soil and that strawberry transplants are not infected. Suppression of the pathogen in soil has routinely been accomplished through preplant fumigation with a combination of methyl bromide and chloropicrin (MB:CP). A typical formulation would be approximately 2 MB: 1 CP (wt./wt.) at 350 lbs per acre. Many alternative treatments have been tested and may prove to be satisfactory, but none have been widely used enough to determine if they are truly comparable to what has historically been the industry standard. Chloropicrin alone can be used, but even rates as high as 200 lbs. per acre may not be fully effective. Chloropicrin combined with telone may be more effective. The commercial product Inline (35% chloropicrin and 65% telone) at 425 lbs/acre was shown to control Verticillium wilt as well as MB:CP in one study. The efficacy of these treatments may be enhanced by the use of VIF (virtually impermeable film) tarps. Various non-chemical methods for treating soil have been tested and thus far none have been shown to be as efficacious as fumigation with MB: CP. However, work on many of these alternative practices is on-going and interested growers should contact their county farm advisor or the California Strawberry Commission to obtain the most current information.

Where fumigation is not used, it would be advisable to have the soil tested for the presence of *Verticillium dahliae.* Private labs offer this service and should be able to provide quantitative information on the infestation level present in a field. Keep in mind that the distribution of the pathogen in soil is not uniform so measures of inoculum abundance are meaningful only in proximity to the areas sampled. For this reason it would be wise to communicate with the lab doing the assay work to determine how best to sample the field.

If soil testing reveals the presence of *V. dahliae* in fruit production fields and fumigation is not used, certain cultural activities may be used to reduce the numbers of microsclerotia. This includes allowing strawberry crop residue to dry on the bed surface before it is incorporated into the soil at the end of the season. Rapid drying will shorten the time available to the pathogen to form microsclerotia within infected tissue and reduce the quantity of these survival structures returned to the soil. In addition, recent research from both small-plot studies and large-plot demonstration studies under both conventional and organic strawberry production systems have demonstrated significant reductions in the numbers of microcsclerotia in soil after rotations with broccoli. Improvements in strawberry fruit yield were also observed when other soilborne pathogens were present. However, the improvements in growth and yield were not equivalent to those obtained in fumigated fields. According to a cost-benefit analysis, the broccoli-strawberry rotation system could be an economically viable option where growers are willing to give up continuous cultivation of strawberries.

Assuming that the pathogen is not already present in the soil, Verticillium wilt will not develop unless the transplants themselves are infected. This is usually not a problem because nurseries, like fruit producers, typically use pre-plant fumigation to suppress the soil population of *Verticillium dahliae.* As noted above, this practice is especially important where strawberry plants are grown in rotation with potatoes. If a less than fully effective fumigant is used and/or the material is applied under sub-optimal conditions (as in cool, wet soil), sufficient inoculum may survive the treatment to cause infections. In this case, it is possible for Verticillium wilt to develop in a manner that can be difficult to detect. Mother plants may not show symptoms until relatively late in the season at which point they are often overgrown to a considerable extent by more vigorous daughter plants (Figure 6). Daughter plants that become infected are likely to remain symptomless. Under these circumstances, healthy appearing plants could develop Verticillium wilt some time after they have been

transplanted into a fruit production field. In this case, susceptible cultivars are likely to show symptoms early in the season and will typically be severely stunted (Figure 1).

Although strawberry cultivars differ in their susceptibility to Verticillium wilt, none are sufficiently resistant to ensure complete control of the disease. However, recently released cultivars are generally much less susceptible than older cultivars. For example, experimental inoculations show that Camino Real and Albion sustain less damage from Verticillium wilt than Camarosa or Diamante. This change reflects the fact that susceptibility to Verticillium wilt is now an important selection criterion in the University of California breeding program. As a result, resistance to Verticillium wilt in UC strawberry cultivars should continue to increase over time.

Figure 6. An experimental nursery production field in which some mother plants (e.g., arrow) are showing symptoms of Verticillium wilt. By the end of the season, these symptomatic plants may be completely overgrown by healthy daughter plants.

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