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Integrated Management of Bacterial Spot on Tomato in Florida[1]

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Introduction

Bacterial spot of tomato, caused by *Xanthomonas campestris* pv. *vesicatoria* (Xcv), was first observed in 1914 in South Africa (Doidge, 1920). This disease can be present wherever tomatoes and peppers are grown, but is especially severe in Florida and the southeastern US when weather conditions (high temperature, high humidity, and rain) become conducive for disease development.

Symptoms

Disease symptoms can be seen in all above ground plant parts. Spots are generally dark brown and circular (can be angular) on the leaves, stems, and fruit spurs (Fig 1). Disease usually start on the lower leaves, and are more visible initially on the underside of the leaves. Spots rarely develop to more than 3 mm in diameter. In some cases, with race T3 of the bacterium, shot holes develop at the center of the spots. On leaflets the spots can easily be confused with early blight, gray leaf spot, or target spot. Bacterial spot lesions form an ooze when cut in half. This ooze is usually visible under a microscope (Fig 2). Lesions of fungal diseases do not ooze. Early blight and target spot (in some cases) lesions have concentric zones. Gray leaf spot lesions are lighter in color and are more uniformly distributed than bacterial spot lesions. When conditions are optimal for disease development, spots coalesce to form irregularly shaped lesions. A general yellowing and blighting may occur on leaflets with many lesions. Often the dead foliage remains on the plant, giving it a scorched appearance. Fruit lesions begin as small, slightly raised blisters. As spots increase in size, they become dark brown, scab-like, and slightly raised. However, they may also be raised around the margins and sunken in the middle. A developing lesion may have a faint prominent halo, which eventually disappears (Jones, 1991; Kucharek, 1994).

Causal Organism

Xanthomonas campestris pv. *vesicatoria* is a motile bacterium, strictly aerobic, gram negative rod which possesses a single polar flagellum. On nutrient agar it grows relatively slowly, and the colonies are circular, wet, shining, yellow, and whole.

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Figure 1. Leaf spots on tomato leaves. Credits: Hank Dankers

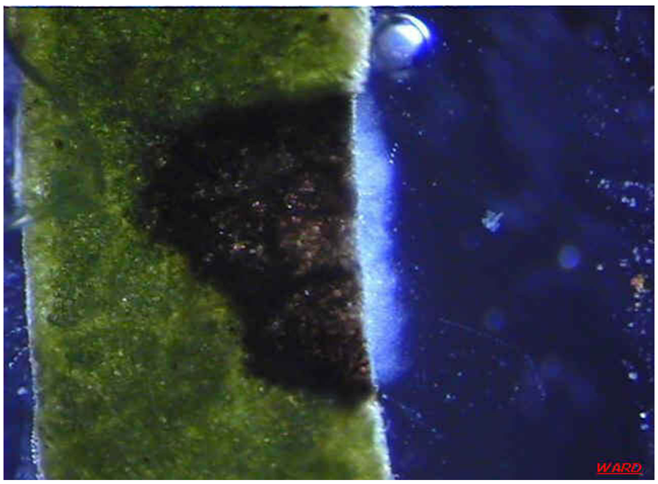

Figure 2. View of diseased tissue under microscope, ooze test. Credits: Hank Dankers

For tomato, this pathogen has four races. Tomato race 1 (T1) was commonly found in Florida until T3 became dominant since its appearance in Florida. Recently race T4 was discovered in Florida. T2 is common in Ohio and other mid-western states (Jones, 1991).

Disease Cycle and Epidemiology

The organism is able to survive on tomato volunteers and plant debris from infected tissue (Jones et al., 1986). Seeds may also serve as a medium for the survival and dissemination of the bacterium. Disease development is favored by temperatures of 24-30 °C and by high humidity and rain. The dissemination of the bacterium within fields occurs by wind-driven rain or irrigation droplets and aerosols, and some cultural practices. Handling plants while plants are wet will help disemination of bacteria (Pohronezny et al., 1990). The bacterium enters through natural openings (e.g. stomates and hydathodes) and wounds created by wind-driven sand, insect punctures, or mechanical means (Jones, 1991).

Disease Management

Cultural practices

Crop rotation should be used in an attempt to avoid carryover on volunteers and crop residue (tomato and pepper). Use disease- and pathogen-free transplants. Do not establish cull piles near field operations. Do not spray, tie, harvest, or handle plants while they are wet. Eliminate solanaceaous weeds such as ground cherry and nightshade in and around tomato fields (Kucharek, 1994).

Biological control

Biological control of the bacterial spot caused by race T1 has been achieved by using Xcv race T3 (T3 strains antagonize the T1s) (Jones et al., 1998, Hert, 2001;) and with other antagonistic bacteria such as *Pseudomonas putida* B56 and *Pseudomonas syringae* Cit7 (Wilson et al., 1997).

Bacteriophages (phages) are an effective biocontrol agent for the management of bacterial spot on tomato (Flaherty et al., 2000). Phages are viruses that infect bacteria. In order to minimize the development of phage resistant bacterial strains, phages were applied as a mixture of several different phages. Coupled with this was the use of host-range mutant phages (h-mutants) to reduce cross-resistance within a bacterium (Jones et al., 2002). Recently, protective formulations were developed to increase longevity of phages on plant surfaces in the field (Balogh et al., 2002). Newly formulated phages performed better than the copper-mancozeb treated and the untreated control in the field. A powdered skim milk formulation may be recommended for field application because it is easy to prepare and apply. Applications of phages in the evening resulted in better bacterial spot control compared applications in the morning. Based on recent results, formulated phages could be applied twice a week at sunset for the management of bacterial spot. A registered product is

Agriphage (AgriPhi, Inc, UT). Currently, this product has FIFRA Section 18 - emergency exemption, and application has been made for FIFRA Section 3 registration. During the past several years, Jones et al. tested bacteriophages for control of the bacterial spot pathogen on tomato. In a field study in which tomato plants were sprayed with phage or copper-mancozeb, or left untreated, bacterial spot severity was significantly reduced compared to the copper-mancozeb treatment and the untreated control. Yield was also affected by phage applications with an increase between 17 and 25% over the other two treatments (Flaherty et al., 2000). Recently, research on bacteriophages has focused on improving the formulation in order to increase survival of the bacteriophage on the leaf surface (Balogh et al., 2002). We have developed new formulations for phage longevity under field conditions and modified the timing of applications to increase bacteriophage efficacy.

Chemical approach

Copper. Copper as a fungicide has been used in agriculture since early 1800's. Soluble copper ions are known to bind tightly to sulfhydryl groups, accounting for its biocidal properties. Free copper ions can penetrate through plant cuticles and cause severe phytotoxicity. Water-insoluble (or low soluble) copper salts (""fixed coppers"") are the solution to this problem and has become the major chemical group for bacterial disease control. Some disadvantages of copper materials are phytotoxicity, reduced copper sensitivity among Xcv strains (in some areas), and environmental impact. Copper ions are not degraded in soil and can accumulate to high levels at locations with a history of intensive copper application (Koller, 1998).

The management of bacterial spot is a challenge in commercial production in Florida due to limited efficacy of fixed copper bactericides and the presence of copper-tolerant strains. Copper materials are protectants. They only affect bacteria on plant surfaces. For bacterial diseases, copper materials are used as part of an integrated management program. Until recently, there were very limited options to integrate with copper for bacterial spot control on tomato . Chemical control originally relied on the application of streptomycin, an antibiotic, and also copper compounds. However, streptomycin lost its effectiveness due to the emergence of resistant strains in the 1960s (Thayer and Stall, 1961), and by the 1980s copper resistant strains emerged as well (Marco and Stall, 1983). Eventually, the copper bactericides also became ineffective in some tomato production areas when used alone (Marco and Stall, 1983). However, it was discovered that the addition of maneb or mancozeb fungicides to the copper bactericides enhanced their efficacy (Conover and Gerhold, 1981; Marco and Stall, 1983). Since then, these copper-mancozeb mixtures have been in use for controlling bacterial spot, although complete control cannot be achieved solely with them. In a fall crop, south Florida growers may apply copper plus mancozeb two or more times per week in an attempt to manage this disease. Control, based on fixed copper bactericides, is not acceptable when weather conditions are optimal for disease development

SAR inducers. Recently, alternative chemical control approaches have been investigated in which chemicals are applied that activate plant defense responses. Systemic acquired resistance (SAR) is a biochemical state of the plant in which the plant develops greater resistance to a pathogen by previous infection by that pathogen or a different pathogen (Sticher et al., 1997). Several substances that specifically induce SAR, such as acibenzolar-S-methyl (ASM) (known as Actigard, Syngenta, NC) and harpin (Messenger, Eden Bioscience, WA) have been investigated. ASM has shown activity against bacterial spot in tomato (Louws et al., 2001) in Florida, Alabama, North Carolina, Ohio and Ontario, Canada. Recent modifications of phages and its integration with Actigard have resulted in significant increases in disease control compared to the standard bacteriophage and copper-mancozeb treatments (Balogh et al., 2002; Obradovic et al., 2002).

Integrated management

An integrated management program against bacterial spot is a key factor for successful tomato production. There are two important approaches to reduce severity and incidence of bacterial spot on tomato in the field: reducing inoculum and minimizing plant susceptibility. Recently, new environmentally friendly technologies have emerged that could be utilized in IPM programs as alternative management tools for bacterial spot. These include the following: a compound (Actigard) which induces systemic acquired resistance (SAR) (ie. increasing natural defense mechanism of the existing commercial cultivars or minimizing susceptibility) and uses phages specific to the target bacterium (i.e., reducing inoculum on leaf and fruit surfaces).

Since fall of 1999, we initiated a new research and extension program in north Florida to fine tune the use of Actigard and phage and to reduce copper use on tomatoes in Florida. In the meantime, we are investigating many new potential materials for integration into tomato health management programs that could ensure economically and environmentally sustainable tomato production in Florida. Based on our intensive research programs on bacterial spot in Quincy and Gainesville (total of 29 field and greenhouse experiments) the following current recommendations have been made for bacterial spot management for fresh market tomato production in Florida:

- Actigard* and copper-mancozeb combination. Actigard needs to be applied every 14 days. The first application should be started as early as possible after transplanting. Reduce copper-mancozeb applications if you are using Actigard. Copper and/or mancozeb may be still needed for some fungal disease control. The label for Actigard has precautins to minimizing yield supression. In north Florida and south Georgia yield reductions due to Actigard have not been observed since 1999.

- Or Actigard* and AgriPhage* combination. This combination might help to eliminate or further reduce copper significantly for the management of bacterial spot. In this program, use Actigard every 14 days. Use phage twice a week, apply before sunset, especially before expected rains and/or immediately after. Add powdered skim milk (0.75 %) and sucrose (0.05 %) as a protectant (from UV and other weather elements) for phages. Copper-mancozeb may be still needed for some foliar fungal disease control. If you have never used Actigard and/or AgriPhage in your production, try it only in limited areas (to determine its suitability). Read all label information carefully.

- Always use the cultural practices mentioned above as a backbone of your integrated program.

Bacterial spot causes serious problems every year on tomatoes in Florida. Results derived from our research program are being used to design an effective IPM program that aims to reduce copper use on Florida tomatoes while maximizing bacterial spot control with environmentally sound disease management practices. Also, by reducing the use of copper based bactericides, the amount of copper that enters the soil system will be diminished.

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