Critical and Emerging Issues: Development and Dissemination of an Integrated Management Plan for Bacterial Canker of Tomato

Summary

The Problem

Bacterial canker, caused by *Clavibacter michiganensis* subsp. *michiganensis* (Cmm) is a serious disease of fresh-market tomatoes in the Northeast. Within the past five years, the incidence of bacterial canker has increased throughout New Jersey and the northeast region, and current management practices for other bacterial diseases of tomato have not been effective against bacterial canker. For many New Jersey growers, bacterial canker is the most serious disease in fresh-market tomato production. In New Jersey, many growers experience some loss due to fruit infection, while a number of growers lose entire plantings to systemic infections. In New York, bacterial canker has become one of the most important diseases of tomatoes. Losses to bacterial canker can vary from none (minimal foliar injury) to total (systemic infection), and are dependent on source of the infection, weather conditions, cultural and disease management practices.

Objectives

1. Identify grower practices that contribute to poor control of bacterial canker.

2. Demonstrate seed heat-treatment as part of an integrated management plan for bacterial canker control.

3. Demonstrate the importance of integrated tactics, including seed heat-treatment, vigorous sampling, and hygienic production practices in an integrated management plan for control of bacterial canker.

4. Promote an integrated plan for managing bacterial diseases in tomato.

Impacts

This project will ultimately result in identifying major weaknesses in current grower management of bacterial canker of tomato, as well as introduce new techniques and tools to growers for preventing bacterial canker infections in tomato. In New Jersey, the technique and benefit of seed heat treatment for control of bacterial canker will be demonstrated for the first time on a large-scale basis. Tomato growers will be able to adopt the full range of effective management strategies developed by this study into a new integrated management program upon demonstration of their efficacy. The use of heat treated seed followed with improved guidelines pertaining to best management practices will help tomato growers reduce the losses due to bacterial canker in tomato production. Furthermore, the guidelines developed from this study will also allow researchers and county agricultural agents throughout the Northeast to develop and implement integrated management programs for control of bacterial canker for tomato growers in their region.

4. Project Description

a. Problem, Background, and Justification

The Current Problem

Bacterial canker, caused by *Clavibacter michiganensis* subsp. *michiganensis* (*Cmm*) is a serious disease of fresh-market tomatoes in the Northeast (12, 19, A. MacNab, personal communication). New Jersey growers harvest over 3,000 acres of fresh market tomatoes valued annually at nearly 28 million dollars. Fresh market tomato production in neighboring states is similar, with New York harvesting 2300 acres at 25.9 million dollars, Pennsylvania with 4000 harvested acres at 13.9 million dollars, and Maryland with 2000 acres valued at 12.6 million dollars (18). Much of the fresh market tomato crop is sold locally, and is a key item in supermarket produce departments as well as farmers markets. Since 2000, the incidence of bacterial canker has increased throughout New Jersey and the northeast. Current management practices for other bacterial diseases of tomato have not been effective against bacterial canker. For many New Jersey growers, bacterial canker is the most serious disease in fresh-market tomato production. In New Jersey, many growers experience some loss due to fruit infection, while a number of growers lose entire plantings to systemic infections. In 2005, heavily infected early tomato plantings on two farms in the northern New Jersey Rutgers Cooperative Research and Extension (RCR&E) Vegetable IPM Program resulted in significant loss of that crop and spread to subsequent plantings. Overall loss was assessed at fifty percent by one grower (Frank Piazza, Piazza Farms and Greenhouses, Phillipsburg, N.J., personal communication). Losses in the ten to fifteen percent range have been cited by others in New Jersey (Marc Phillips, Phillips Farms, Milford, N.J. and Gary Donaldson, Donaldson Farms, Hackettstown, N.J., personal communication). In New York, bacterial canker has become one of the most important diseases of tomatoes (16). Infections in New York are reported to be more localized, with some growers consistently affected. On these farms, 20-30% loss is common (J. Mishanec, personal communication). Often, infested seed is cited as an inoculum source (2, 3, 7, 9,14,15), although field sources have also been noted (15). Recent work in New Jersey indicates that both seed and field sources are important (13). Losses to bacterial canker can vary from none (minimal foliar injury) to total (systemic infection), and are dependent on source of the infection, weather conditions, and cultural and disease management practices. This is particularly true with fresh market tomato production, as cultural practices such as pruning, tying and multiple harvests cause injury to plants that enable bacterial pathogens to gain entry directly into the plant vasculature.

At times growers have claimed that disease presence appears to have been linked to one variety, from which it spread to other subsequent varieties and plantings. Growers consider that an initial infection, beginning with one variety in one year, results in a perennial bacterial canker problem on the farm. Extremely low rates of seed infection and a long latent period prior to symptom development may render commercial seed testing and certification procedures unreliable (8). Further, growers who produce transplants from seed lots with a low incidence of infection can increase the number of infected seedlings with greenhouse procedures that permit the spread of bacterial pathogens (20). Reused tomato stakes are often suspected to be a source of infection, and *Cmm* has been cultured from untreated tomato stakes that were used in an infected crop in 2004 (13).

Many growers opting to treat tomato stakes use a 5% or stronger sodium hypochlorite (bleach) solution (5.25% NaOCl) in preparation for use the following season. While ELISA is a valuable tool for indicating the presence of *Cmm* on live plant tissue, ELISA testing is of limited value when testing bleached stakes, as the kit reacts with a residual extra cellular polysaccharide from *Cmm* and does not indicate whether live cells are present. Moreover, culturing *Cmm* from live plant tissue, debris or stakes and then inoculating tomato plants to determine the viability of recovered bacteria is problematic as tomatoes may not show symptoms for many weeks post-inoculation, making timely results unattainable during the course of a crop cycle.

Stakeholder Needs

The primary needs expressed by tomato growers in New Jersey are for i) tools and resources for identifying initial sources of bacterial canker infection in their production systems and, ii) for those tomato growers with aggressive bacterial management programs, what current management practices are improperly performed or inadequate for bacterial canker control. One example, Piazza Farms, vegetable growers and producers of tomato transplants for other growers in the region have stated that "some seed lots must be infected and we don't know from year to year which ones are bad, so we need to know how best to treat the seed. We also are not clear on other production practices like chlorine treatment of stakes; we're not sure if it really works." Additionally, the New Jersey Tomato Advisory Committee, an industry group comprised of growers, agribusiness representatives and researchers charged with advising the NJAES on the research needs of the tomato industry has identified bacterial canker as a threat to tomato production and has provided recent funding for limited investigations into seed treatment and disease epidemiology in New Jersey.

Placement of the RCR&E Vegetable IPM Program

RCR&E Vegetable IPM Program personnel work directly with over 40 tomato growers in New Jersey, providing regular, on-farm IPM services. With larger producers, these services may begin with seed-treatment and subsequent discussion of bacterial management throughout the production of transplants. IPM personnel participate in meetings of the New Jersey Tomato Advisory Committee, and the RCR&E Vegetable Working Group. Additionally, RCR&E IPM staff members correspond with industry personnel and researchers both within and outside the northeast region about problems and developments regarding bacterial canker of tomatoes. Contacts with local growers, as well as other members of the agricultural and research communities, place RCR&E IPM Program personnel in a particularly good position to address the growing problem of bacterial canker of tomatoes.

Beneficiaries of New Research

The primary beneficiaries of this research will be tomato producers. Currently, yield losses from bacterial canker range from none to 100%, depending on the source and initial severity of infection and the success of utilized management practices (if any). Beyond the economic loss associated with yield reduction, there are costs involved in increased use of anti-bacterial agents in the field. Many growers, without proven alternative management solutions, resort to repeated field applications of copper hydroxide, hydrogen dioxide (OxiDate), and systemic acquired resistance (SAR) inducing products (Actigard, Messenger) to limit the spread of in-field infections. Although chemical control in the field is of limited value, growers are struggling to find effective alternative means of control. In 2005, a nine acre tomato grower in northern New

Jersey applied nearly five thousand dollars worth of anti-bacterial agents on the crop, not including other materials targeting foliar fungal infections (Gary Donaldson, personal communication). Piazza Farms (mentioned above) have experienced significant difficulties with this disease during the past three years, and as producers of transplants for other growers, stand to benefit from improvements in understanding and managing bacterial canker. Marc Phillips (personal communication) has had good success, limiting bacterial canker to insignificant levels since he began heat treating all seed at the Rutgers University Sustainable Agriculture Research Farm. Positive cases like this provide even greater incentive to identify any management practices that may be contributing to success or failure in canker management. Successful strategies will be shared with the community of producers, extension and support personnel, thereby benefiting the entire industry.

Relevant Research

Increased research on bacterial canker followed a serious bacterial canker epidemic in the North American mid-west in the 1980's. Much of this work was reviewed by Gleason (9), and included advances in pathogen detection, isolation and epidemiology. An understanding of the origin of infection is critical, and a focus of research has been on seed as the source of primary inoculum, with various seed treatments evaluated for control of *Cmm* (4, 7). Consistently, hot water treatment of tomato seed has been among the most effective treatments for minimizing *Cmm* inoculum while maintaining acceptable germination rates. Subsequent to these studies, Dr. Sally Miller of the Ohio State University produced an extension publication including procedures for treating vegetable seed to eradicate pathogens on and within seeds (17) as well as developing a detailed procedure for heat treatment of vegetable seed (unpublished). Field sources of infection have received consideration as well. Fatmi and Schaad (6), and Chang et. al. (3) studied overwintering survival of *Cmm* on tomato debris under differing conditions, and recent work by the RCR&E Vegetable IPM Program has demonstrated survival of *Cmm* on tomato debris, perennial horse-nettle (*Solanum carolinense*), and tomato stakes (unpublished). Greater understanding of the activity and efficacy of the SAR inducing product acibenzolar S-methyl (Actigard), against *Cmm* in tomato seedlings has been provided by Baysal, et. al. (1). Dissemination of *Cmm* in the greenhouse and in the field has been studied extensively (3, 13, 20). Research has shown that seed infection does not adversely affect germination (10), however infected tomato plants are often asymptomatic for a period of weeks (7). This results in growers unsuspectingly transplanting infected plants into the field. The long latent period makes early diagnosis difficult in tomatoes at a period when rapid determination of *Cmm* presence and pathogenicity are beneficial. Gitaitis (8) has shown that the four o'clock (*Mirabilis jalapa*) produces a hypersensitive reaction in leaves challenged with *Cmm* within 48 hours, making this a practical diagnostic tool where infection is suspected. In recent years, Northeast Region cooperators have produced fact sheets and other informational material regarding bacterial canker in tomatoes (5,11). Extension resources contain current information on inoculum sources and management strategies for bacterial canker. Despite increased understanding of various aspects of the disease, bacterial canker continues to plague fresh market tomato production in the northeast, either because the information is not getting to the producers, is not implemented by the producers, or is not complete. As bacterial canker has increased in New Jersey, the RCR&E Vegetable IPM Program has responded with small-scale research projects focused on identifying inoculum sources and on the development of a comprehensive management plan.

Recent Work in New Jersey

IPM staff purchased two bench-top, thermostatically controlled water baths with funds provided by the NJAES prior to the 2004 growing season. At the request of the New Jersey Tomato Advisory Committee, RCR&E IPM staff undertook a study in 2004 to determine likely inoculum sources of the disease. In the study, a cooperator with no history of bacterial canker on the farm prior to 2003 agreed to differentially treat seed lots (water bath heat-treatment and sodium hypochlorite treatment) of the same variety. ELISA tests on seed in both lots tested negative for *Cmm* after each treatment, although the size of the original seed lot allowed for only 100 seeds of each treatment to be tested. Tomato plants grown from these seed lots were planted into two different fields, one following the infected tomato crop of 2003; the other rotated out of vegetables for 30 years. In the non-rotated field, disease symptoms developed uniformly throughout the field, presumably from undecomposed, infested plant debris. In fact, *Cmm* had been recovered from this debris prior to planting the 2004 crop. In the rotated field, initial canker symptoms were found in one plot of plants grown from sodium hypochlorite treated seed. Results of the study strongly suggest that a very low number of initially infected plants (possibly one plant that appeared systemically infected) were the cause of the field infection. Infested seed was the likely source, as the majority of the plants in the field were grown from heat-treated seed and symptoms did not initially appear in those plots. Currently, four New Jersey tomato growers heat-treat seed, and have not experienced problems with germination when done properly. Heat-treatment of tomato seed has been shown to greatly reduce bacterial pathogens both on and within the seed coat (7), and its adoption as a management tool for bacterial canker has shown promise in New Jersey.

In 2005, several tomato growers in the northern counties experienced bacterial canker to varying degrees. The in-field control programs of these growers may be described as aggressive due to their use of anti-bacterial agents, although it was apparent that not all beneficial sanitary practices were observed uniformly among growers. Further, several of these growers indicated that one variety in particular was the source of the infection in 2005. The variety was consistent among the growers. A uniformly problematic variety in one year supported the assertion that seed is a primary source of inoculum. However, differing levels of management and prevention among growers made conclusions difficult. In order to begin to ascertain from which source infections originated and what weaknesses existed in grower management practices, program staff developed a questionnaire to help identify common sources of the disease as well as common practices among growers who experienced success at managing bacterial canker. Five growers from different areas of the state participated in the questionnaire. Results showed that one variety consistently developed symptoms first among northern area growers (unpublished data). Additionally, symptoms were severe and spread to subsequent plantings, although in some cases symptoms were not as severe in later plants. Spread was predictable, as the growers used insufficient measures to prevent bacterial dissemination among varieties in the greenhouse during transplant production and in the field during pruning and tying events.

In coordination with previous work and with limited, short-term funding an integrated management plan for bacterial canker control can successfully be developed and adopted. First, several important issues must be addressed.

1. Growers need to understand all necessary measures in an integrated management plan for proper control of bacterial canker.
2. The benefits of seed heat-treatment must be demonstrated as an important component of an integrated management plan to tomato growers; and resources for seed heat-treatment must be available for growers.
3. Grower management practices must be properly monitored and documented in order to determine where and why breakdown in bacterial canker control occurs and what best management practices should be undertaken to help reduce losses.

b. Objectives and anticipated impacts

Objectives

1. Identify grower practices that contribute to poor control of bacterial canker.

2. Demonstrate seed heat-treatment as part of an integrated management plan for bacterial canker control.

3. Demonstrate the importance of integrated tactics, including seed heat-treatment, vigorous sampling, and hygienic production practices in a management plan for control of bacterial canker.

4. Promote an integrated plan for managing bacterial diseases of tomato.

Anticipated Impacts

For growers who have agreed to participate in this project, the following impacts are anticipated:

1. Increased utilization of IPM techniques in managing bacterial canker of tomato.

2. Economic improvement resulting from adoption of IPM techniques.

3. Training of all participating growers and associated farm personnel in IPM tactics for control of bacterial canker will take place through this project.

Upon completion of the project, the following impacts are anticipated:

Development and dissemination of IPM related information to the tomato growing community, and industry and extension support personnel, resulting in greater understanding and implementation of IPM tactics for management of bacterial canker.

c. Approach and Procedures:

Objective 1. Identify grower practices that contribute to poor control of bacterial canker.

Year 1 (2006)

February 2006

A brochure entitled "Bacterial Canker of Tomato: Background and Management Strategies" has been developed detailing all current aspects of an integrated plan for managing bacterial diseases of tomato (Appendix A). The brochure contains current recommendations for canker management and the use of heat-treatment as a new tool for managing seed-borne bacterial disease and will be distributed to all grower cooperators. The brochure will be available to all tomato growers in New Jersey during and after this study. Ten New Jersey growers who have agreed to participate in the project will be given the brochure and asked to follow all applicable procedures (some will not apply to those who purchase transplants). The brochure contains a checklist for growers to follow which allows them to record what management practices have been done during the production season.

March-August 2006

RCR&E IPM staff will establish a site at the Rutgers Sustainable Agriculture Research and Extension Farm in Pittstown, New Jersey for participating tomato growers in the northern counties to treat tomato seed. Access to RCR&E water baths will be scheduled so that all growers are able to complete the treatment conveniently. RCR&E IPM staff will supervise the use water baths. Grower compliance with all procedures will be documented by RCR&E IPM; thereby aiding identification of which practice(s) (or absence of practices) contributes to poor control should it result.

September – October 2006

Final assessments on the first year of the project will occur. Discussions with grower cooperators and RCR&E Plant Diagnostic Laboratory personnel will take place with combined input helping to amend practices for the second year as necessary.

Year 2 (2007)

The timetable for year 2 will be the same as the previous year, with final assessments by grower cooperators on the ease of compliance with management tactics.

Objective 2. Demonstrate seed heat-treatment as part of an integrated management plan for bacterial canker.

Year 1 (2006)

February-March 2006

Participating growers who produce their own seed will have access to RCR&E IPM Program water baths and will heat-treat tomato seed with the supervision of RCR&E IPM staff. A grower-cooperator producing transplants for other growers (and currently use the protocol outlined by Dr. Miller, and advocated by RCE) will be inspected by RCR&E IPM staff to insure that appropriate protocols are followed (Letter of agreement Appendix B).

Year 2 (2007)

February – March 2007

The same timetable will be observed for heat treating seeds as in the prior year.

Objective 3. Demonstrate the importance of integrated tactics, including seed heat-treatment, vigorous sampling, and hygienic production practices in a management plan for control of bacterial canker.

Extensive inspections and field surveys will be conducted by RCR&E IPM before and during the growing season. These procedures will help insure grower compliance with management strategies, help identify sources of inoculum common among farms, help identify production practices that contribute to poor control, and demonstrate the importance of all practices in the integrated plan. Inspections and surveys will include:

Year 1 (2006)

February – April 2006

Pre-seeding inspection and survey of varieties, seed heat-treatment and greenhouse sanitation procedures for participating growers who produce transplants.

March – May 2006

Pre-transplanting inspection and survey of fields to be planted in tomatoes by RCR&E IPM for the 2006 growing season. The survey will include a history of bacterial canker on the farm, field history, treatment of tomato stakes and involve removal of crop and weed debris, stakes that are to be reused, and solanaceous weed samples (if present) for ELISA testing. In the case of tomato stakes, ELISA testing will be conducted on surface wood that is planed off of a minimum of ten stakes per planting. Attempts to culture *Cmm* will be made from any material testing positive for *Cmm* by ELISA. Cultures suspected of being *Cmm* based on colony appearance on diagnostic media will be assayed with *M. jalapa* for confirmation of *Cmm* and pathogenicity. All ELISA testing and laboratory diagnostic work will be conducted by the RCR&E Plant Diagnostic Laboratory. Information derived from these activities will help identify inoculum sources and permit growers make informed choices regarding field selection.

May-August 2006

In-season surveys of participating fields and cultural practices. On a bi-weekly basis, participating fields will be surveyed by RCR&E IPM for the presence of potential solanaceous weed hosts of *Cmm* (*S. carolinense* in particular), as well as visual symptoms of bacterial canker on the crop. Concurrently, leaf samples from the tomato crop and solanaceous weeds like horsenettle and the nightshades (if present) will be removed for ELISA testing. Growers will be surveyed regarding compliance with all in-field management strategies, and asked to record dates of significant field events such as staking, pruning, tying and harvesting.

Year 2 (2007)

The timetable for testing and surveying will be the same in year two as in the prior year, with amendments made to procedures only as deemed necessary by the investigators in agreement with grower cooperators and the RCR&E Plant Diagnostic Clinic personnel.

Objective 4. Promote an integrated plan for managing bacterial diseases of tomato.

Year 1 (2006)

February 2006 - The brochure entitled "Bacterial Canker of Tomato: Background and Management Strategies" will be distributed to all grower cooperators.

November 2006 – February 2007: Progress reports on the project will be presented at state and regional meetings where growers, industry representatives and Extension personnel will be present. Examples include, but are not limited to: New Jersey Agribusiness Association Annual Meeting (Nov, 2006), Mid-Atlantic Vegetable Workers Conference (November, 2006), New Jersey Vegetable Growers Association Annual Meeting (Jan., 2007), and the Northern New Jersey Vegetable Growers Meeting (Feb., 2007). The website: Rutgers Tomato will include a progress report on the project as well as any updated information regarding management practices for bacterial canker of tomato.

Year 2 (2007)

February/March: "Bacterial Canker of Tomato: Background and Management Strategies" will be amended if necessary, and redistributed to participating growers.

June – September: Findings from the project will be presented at RCR&E sponsored grower meetings occurring throughout the summer, and published in The Plant and Pest Advisory Newsletter, a weekly NJAES publication for the vegetable growing industry.

November 2007 - February 2008: A final report on the project will be given at all appropriate state and regional meetings including the annual meeting of the RCR&E Tomato Advisory Committee. The website: Rutgers Tomato will also include a final report with all available bacterial canker management information for tomato growers.

All grower practices will be evaluated for compliance by RCR&E IPM. Further, the appearance of canker symptoms (if present) will be correlated to specific events or cultural practices. This, combined with frequent sampling and ELISA testing, will help determine whether the appearance of bacterial canker is related to non-compliance with management procedures, or whether current procedures are not adequate. Additionally, this process will help identify major sources of inoculum such as from heavily infested soil, old debris, stakes and potential weed hosts, and its dissemination by field-related cultural practices such as staking, tying or pruning. The project has the support of the New Jersey Tomato Advisory Committee.

d. Evaluation

Determination of whether Objective 1 has been met will be based on documented compliance with prescribed IPM procedures as outlined in the bacterial canker management brochure in combination with individual grower success at preventing or managing bacterial canker. During each study season, all grower practices (those used as well as omitted) will be documented. Additionally, each occurrence of *Cmm* on living plant material, debris or stake will be documented for each farm. At the end of each study season, practices will be tabulated along with the presence of *Cmm* in any sample and the appearance and severity of bacterial canker in any planting. In this manner, production practices common to growers experiencing difficulties with bacterial canker may be identified as having contributed to loss of control. Alternatively, common practices among growers experiencing success in controlling bacterial canker will be identified.

Heat treatment of seeds (Objective 2) or purchase of transplants grown from heat treated seed will be required of all participants. Documentation of the appearance and severity of bacterial canker in any planting will permit the evaluation of seed heat treatment as a viable tool. For example, the absence of systemically infected (severely cankered) plants is an indication that seed is not the primary inoculum source.

Grower acceptance of integrated tactics for managing bacterial canker (Objective 3) will be contingent on the program resulting in improved disease control. While this outcome is expected, growers must comply with as many features in the program as possible, with compliance documented and disease occurrence (if any) documented and categorized as to its' nature (systemic infection versus secondary). Success of the program will be determined by the number of participating growers experiencing improvement in disease management and committing to continued adherence to the IPM plan. In addition to RCR&E personnel evaluating the efficacy of bacterial canker management, initial participating growers will be asked to evaluate the management regime both for efficacy and ease of implementation. At the termination of the project, participants will be asked to identify which practices they will maintain as part of their regular management program.

Education of growers and related industry personnel and promotion of an integrated management plan for bacterial canker (Objective 4) will occur via mass distribution of any developed informational materials to tomato growers upon successful completion of the project. Results of the project will also be disseminated through reports at local and regional grower meetings. Numbers of individuals receiving printed and presented information will be documented and included in Rutgers Cooperative Research and Extension Vegetable IPM Program annual reports. A website currently under development (Rutgers Tomato - www.rcre.rutgers.edu/tomato/) for tomato related information in New Jersey will be an internet based clearinghouse for all information developed through the project. Site usage data will be documented and made available via Rutgers Cooperative Research and Extension Vegetable IPM Program annual reports. County agricultural agents, crop consultants and members of the tomato advisory committee will receive educational material developed as a result of this project and training at meetings of the Tomato Advisory Committee as well as at seasonal twilight meetings when appropriate. This information will ultimately result in effective bacterial management strategies becoming standard industry practices in the state, with the anticipation that they will also be adopted regionally.

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