

Title: Combined Resistance to Late Blight, Early Blight, and Septoria Leaf Spot in Tomato, and Complementary Fungicides for NE and other Temperate Production Regions

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(i) Project Type: Joint Research-Extension

(ii) Project summary This Research & Extension project (\$164,249 PL89-106, \$10,720 Smith-Lever) targets improved control, with reduced pesticide load, of early blight (EB), late blight (LB), and Septoria leaf spot (SLS), the 3 main fungal diseases of tomatoes in the eastern US. These diseases occur in all NE states to the Southern region and are repeatedly listed as priority items. Another priority is strobilurin resistance found in EB isolates in NY, NC. This project unites breeders, pathologists, horticulturists, and conventional & organic growers in 4 states and two regions to meet priorities by developing LB/EB/SLS resistant tomatoes (adding SLS resistance to a LB/EB resistant line), and testing disease response of these lines with reduced sprays of low EIQ fungicides. Severe SLS damage across the NE in 2008 demonstrates the need for this resistance. We address strobilurin resistance by selecting appropriate replacements, scheduling use (TOM-CAST), and assess how reduced sprays and plant resistance can improve control and reduce grower costs. Conventional and organic grower-cooperators will serve as multipliers. The objectives are: 1 & 2) Combine SLS, LB and EB resistance in elite tomato lines, testing disease response and horticultural; 3 a & b) Determine efficacy of four fungicide treatments for disease control with & without genetic resistance (NY) then compare the best timings on lines with & without EB/LB/SLS resistances (NY, VA and NC); 4&5) Test EB/LB/SLS lines and hybrids in multiple sites (NY, WV) for control and horticultural properties. This project covers all 14 priorities listed in NE-IPM RFP, as explained in Justification.

Combined Resistance to Late Blight, Early Blight, and Septoria Leaf Spot in Tomato, and Complementary Fungicides for NE and other Temperate Production Regions

(i) Problem, Background and Justification

Problem. This project addresses control of Late blight (LB), Early blight (EB) and Septoria leaf spot (SLS) in tomato production in New England (6 states), Northeast (NE: NJ, NY, PA), mid-Atlantic (VA, NC), North Central (MI, IN, OH). Tomato is an important crop in these states and regions. The combined 2007 acreage in NY, NJ, PA, VA, & NC was 16,600A harvested, with a value of over \$187 million (USDA Statistics, 2007). Disease control is a major concern across these regions; many fungicide sprays are used to protect yields and quality. LB is a foliar/fruit disease occurring in most US tomato growing regions. Significant losses from LB occur in organic fields and also in conventional production when fungicide sprays were missed due to extended rain (MacNab, 2004). EB and SLS are common foliar disease in the NE, mid-Atlantic, and Mid-West states. In favorable weather, defoliation due to EB can exceed 70% in unsprayed plots (Zitter & Drennan, 2004), with 30% yield loss and 10% fruit size reduction. In cool wet weather SLS can cause serious defoliation and up to 50% yield reductions (Ferrandino & Elmer, 1992; 1996). Spray reductions were achieved with forecasting t programs Tom-Cast (EB), or Blitecast (LB) (<http://www.ipmcenters.org/cropprofiles/docs/NJtomatoes.pdf>; Cowgill et al, 2005; Keinath et al, 1996). These programs did not consider EB/LB resistant varieties since they were not available. In a previous NEIPM funded grant (Mutschler et al, 2005) LB/EB resistant lines were created, and trials of these lines showed that optimal control is obtained by growing LB/EB hybrids combined with minimal sprays of strobilurins, coppers or biologicals for full EB control (Zitter et al, 2005; Zitter & Drennan, 2008a, b). However, severe SLS occurred when growing EB/LB varieties with minimal sprays (Mutschler et al, 2005), revealing an emerging issue for growers using the LB/EB varieties. Another emerging issue is widespread appearance of EB pathogen resistant to strobilurin fungicides favored for EB control. This could dramatically increase reliance on protectant fungicides and increase the number of sprays used. Excessive spraying results in increased costs for growers, increased risks of compound release to the environment and rural community, and increased risks of residuals for consumers.

2. Background. The diseases LB, EB, & SLS are repeatedly cited as high priorities by tomato growers in New England, Northeast and Mid-Atlantic States. EB, LB & SLS ranked 2nd, 3rd, and 4th in importance in a 2002 survey covering CN, ME, MA, NH, RI, and VT, (Anon. 2002). The Vegetable IPM Priorities, covering nine NE, states gave high priority to “*Phytophthora*” and “other fungal diseases” of tomato in 2003 (http://northeastipm.org/work_vegpriority2003.cfm) and in 2003-2005, & 2007 (http://northeastipm.org/work_vegpriority2007.cfm). In other regions, The 2007 Pest Management Strategic Plan identified leaf spots (EB & SLS) as devastating in periods of wet weather in VA, NC and DE (<http://www.ipmcenters.org/pmsp/pdf/SRTomato.pdf>). The NC crop profile lists EB as a statewide concern, SLS in eastern NC, and LB in western NC (<http://www.ipmcenters.org/cropprofiles/docs/nctomatoes.pdf>). EB & SLS were noted as major concerns in OH, IN & MI. (<http://www.ipmcenters.org/cropprofiles/docs/mitomatoes.pdf>). These concerns are echoed in letters from extension specialists NY (Bornt, Mishanec, Hadad, and Reid), VT (Hazelrigg), PA (Gugino) and the NC Tomato Growers Assoc. (Sprague).

Strobilurin fungicides were widely adopted for tomatoes due to their broad protection against fungi & oomycetes and their low EIQ (Environmental Impact Quotient). Strobilurins are site-

specific QoI fungicides (Köller et al, 2001). The F129L mutation governs mild resistance to QoI fungicides, such that solo applications of QoI's result in reduced disease control for isolate with the F129L substitution. Reduced sensitivity to azoxystrobin of *A. solani* (F129L) was reported in potato in many states (Pasche et al, 2005, Rosenzweig et al, 2008) and confirmed for *A. tomatophila* in tomato in NY and NC (Zitter and Ivors unpublished, respectively, see letters from Bornt, Hazelrigg, & Gugino). As a result, strobilurin recommendations must be changed and combination mixtures being developed by chemical companies must be evaluated.

Fungicide use is critical for SLS, LB & EB control in conventional production. New England growers average 6 sprays/season (Anon., 2002); fungicides used were protectants (fixed coppers, (chlorothalonil, & maneb/mancozeb), plus azoxystrobin. An October 2008 survey (23rd Tomato Disease Workshop) indicated more sprays/season in the East, South, and Mid-West (Zitter, unpub.). Strobilurin products combined with other chemistry are now sold due to strobilurin resistance. The combination products (Quadris Top, Quadris Opti & Pristine) gave superior EB & SLS control in a 2008 field trial of standard tomatoes (Zitter & Drennan, 2009a). In a 2nd trial using EB/LB hybrid NC06115, a low EIQ program using Quadris Top gave near perfect control under intense disease pressure, and had a EIQ of 113 vs. 350 EIQ for a standard chlorothalonil program (Zitter & Drennan, 2009b). Coppers are routine organic options for SLS, LB & EB control (Joslin & Taber, 2003; Alexander & Waldenmaier, 2000; 2001), but a combination of copper & *Bacillus subtilis* (Serenade) performs better (Hausbeck & Cortright 2003; Wszelaki & 2005). Without disease resistant varieties, weekly applications of approved chemicals are required in organic fields, but results are usually unacceptable (Wszelaki & Miller, 2005).

When trials of LB/EB lines showed the need for SLS resistance, we obtained germplasm from prior programs (Tu & Poysa, 1990; Poysa & Tu, 1993). Screening the materials and their progenies for 2 generations obtained a line fixed for a strong SLS resistance (071733-1) (Mutschler & Zitter, unpub). Using 0 to 5 scales of no to high disease, 071733-1 had foliar ratings and stem ratings of 3.7 and 0.0, compared to 6.6 and 4.0 for the susceptible control, and the lesion size and number of pycnidia per lesion of 071733-1 were only 36.5% and 2.3% that of the susceptible controls. Although SLS resistance was transferred from *L. hirsutum*, the 071733-1 has productive determinate vines with medium-sized round fruit close to type. The F1 of the LB/EB parent with the SLS lines produce F1 hybrids with SLS resistance nearly as strong as the SLS parent, and segregation for SLS in the F2 generation fits a 3R:1S ratio indicating control by one nearly dominant gene. The breeding program has already made considerable progress, starting with F2 plants selected for SLS and fruit type, generating homozygous SLS F3 and F4 plant materials carrying resistance to EB and LB for use as the starting materials for this project.

Growers will be involved with on-farm research/extension activities in this project. The organic grower (Jean-Paul Courtens 1,000 CSA clients, see letter) and conventional grower (Tim Stanton field and high tunnel, see letter) were cooperators on the prior NEIPM project testing LB/EB tomato hybrids, and are supporters for the need for SLS control, and the use of genetic resistance in the NE region. Our Cooperators in VA and NC will also be working with growers in their area (see Schaer letter). Another set of stakeholders are the seed companies, who produce/sell tomato seed to growers. Seed companies readily accepted LB/EB lines, resulting in LB/EB hybrids now available, and are interested in using the EB/LB/SLS lines (see Cook letter). Working with the seed companies enables them to produce hybrid varieties with multiple resistances, providing growers with greatest choice of resistant varieties. It is a win-win interaction that provides the greatest benefit to all for the fewest research dollars.

Justification Current technologies/practices for EB/LB/SLS control in tomato are inadequate, using excessive amounts of high EIQ compounds yet still failing to adequately control these critical diseases. In this project, the completion of LB/EB/SLS lines, and testing disease control in these lines/hybrids with and without low EIQ supplemental fungicides (Kovach et al, 1992) using Tom-Cast, (<http://www.nysaes.cornell.edu/recommends/>) will allow us to make accurate recommendations for use of triple resistance in areas with different levels of disease pressure, for traditional or organic production. One part of our strategy is development of LB/EB/SLS lines, using existing LB/EB and SLS lines. Since the resistance to EB, and possibly also that to SLS, does not provide full protection, the 2nd part of this strategy is to determine the best low EIQ sprays to supplement the disease control provided by the resistances. These treatments will be applied using a reduced spray schedule by following Tom-Cast. This project covers all 14 priorities in the NE-IPM RFP (Table 1). By evaluating newer, more sustainable products, we will reduce the need for conventional fungicides and substantially reduce copper required for disease control in organic operations. Based on prior releases, we are confident that seed companies will incorporate triple resistant lines with good type into their varieties, which would be adopted by growers to maximize yield and quality while reducing costs. Working with organic and conventional growers who are proven innovators, willing to inform their peers, will attract the largest audience for adoption of our findings. Since tomato is a widely grown vegetable, this project will benefit growers (and other stakeholders) and reduce fungicide usage and EIQs in states of the NE, mid-Atlantic, and Midwest regions. Without the use of triple resistant lines and information on low EIQ sprays to use, growers would continue to suffer losses in yield and quality due to these diseases, and continue excessive use of high EIQ fungicides, raising tomato production costs and negatively impacting the environment.

Table 1. The priorities of the NE-IPM program covered by this program

1. Will reduce environmental risks through reducing reliance on pesticides for control of EB/LB/SLS and determining supplementary pesticides with the lowest EIQ that complement LB/EB/SLS lines.
2. Will reduce risks to human health through supporting tomato production with minimal risk of pesticide residue, including supporting organic production of tomatoes.
3. Has stakeholder support: support and priority as cited in the background above.
4. Focused on a pest/crop in at least five states/ cropping regions: since LB/EB/SLS are problems of tomato production in nearly all of the NE states, plus NY, PA, NJ, NC, VA, & Midwest (OH, IN MI).
5. Will fill a unfilled niche since the project addresses the need for new SLS resistance and for alternate low EIQ strategies for new strobilurin resistant <i>Alternaria</i> strains.
6. Involves three or more states in an active partnership, including in NY, WV, VA and NC.
7. Will advance IPM soon; spray trials results immediately useful for current LB/EB hybrids. Variety release can be rapid. Work from 2005 NE-IPM grant contributed to current LB and LB/EB hybrids.
8. Is interdisciplinary, involving a plant breeder, plant pathologists, and extension specialists.
9. Reduces dependency on chemical pesticides through use of triple disease resistance supplemented with minimal sprays (TOM-CAST) with low EIQ compounds.
10. Has significant economic implications: reduce cost of disease control for all growers in the regions.
11. Serves an "underserved audience"; involved active cooperation 1890 land-grant institution and it's organic growers participants
12. Addresses emerging problems, specifically of the need to control SLS in new varieties resistant to EB and LB and to address control of strobilurin resistance <i>Alternaria</i> strains.
13. Results are will be adopted by the target audience: seed companies already LB/EB lines, and have requested SLS lines, grower indicate high priority LB/EB/SLS control and are involved in project.
14. Advances a more cost-effective IPM practice: use of a resistant variety imposes little extra costs, done very easily; reduction in the number of sprays reduce costs of disease control.

ii Objectives and Anticipated Impacts

Objective 1: Combine SLS resistance with LB and EB resistance in high quality tomato line (“research” component)

Overview: The plan for transfer of SLS resistance follows a backcross plan similar to the one that was successful in creating the LB/EB lines (Kim and Mutschler 2005, Mutschler, unpub.). This process was extremely rapid since. 1.) Several backcrosses to tomato were already made in development of SLS line 071733-1. 2.) The transfer of nearly dominant single gene allows screening for SLS in heterozygotes, halving the number of generations needed for the transfer. 3.) One can use three generations per year in tomato breeding. 4.) Use of larger population sizes, facilitated screening young plants, increases our ability to select strongly for desired type, and progress rapidly.

Anticipated Impact: The work in this objective will develop fresh market tomato lines with horticultural type adapted to the NE/mid-Atlantic that are resistant to SLS, EB and LB, the three major fungal/oomycete pathogens that plague tomato production throughout much of the eastern US. This material will be used in summer of years 2 and 3 in objectives 3 and 4 to determine the a) value of heterozygosity vs. homozygosity for SLS control, b) determine role of genetic resistance without any spray applications, c) determine the spray program/compounds that best support disease control in tomato and have the lowest final EIQs. Further impacts are discussed in the Anticipated Impact Summary, below.

Objective 2: Testing disease response and horticultural type in triple-resistant lines and hybrids. (a “research” component)

Overview: In some ways, this objective is a necessary service for the other objectives. The work in objective 1 is dependent on trials to test materials in development for response to SLS and EB in the first summer, as well as fruit quality, to more finely assess and select lines to advance in year 2 for all of the other objectives. Similarly, the screening work of the best lines and their hybrids in year 2 will determine the materials to be included in year 3 of objective 3 and 4. Another service entailed in this work is the production of the seed to be used in the regional trials in objectives 3 and 4. This requires manual pollinations under greenhouse conditions (space charges plus manpower) during the winter. This will be done in conjunction with the winter greenhouse work of the breeding program.

Anticipated Impact: This work is critical to the overall project; however the impact of this objective is indirect, through the generation of information and the production of seed supporting continued progress in objectives 1, 3, 4, and 5.

Objective 3a: Determining the efficacy of four fungicide treatments (a reduced spray schedule, TOM-CAST-18 and TOM-CAST-25 and an organic treatment) for the control of SLS with or without genetic resistance. (a “research” component)

Overview: Prior work showed that genetic resistance provides excellent control of LB and good tolerance for EB, and that the SLS resistance available significantly reduces inoculum production. We recognized that under heavy disease pressure (applied in our research plots) that the level of EB-tolerance and perhaps SLS-resistance can be improved with minimal fungicide

inputs. We will address what these minimal fungicide needs may be by looking at four fungicide programs: 1) designed for organic production; 2) and 3) that capitalizes on weather-based monitoring (TOM-CAST) to initiate spray applications at two disease severity values (18 and 25); and 4) a program with fungicides applied on a 14 day schedule. The plant material to be tested will be NC33EB-1 (SLS susceptible) and three new SLS resistant lines in inoculated plots. The focus of the screens is on SLS in year 1, and adds EB in year 2, after work in Objective 2 above has confirmed homozygosity of EB resistance in the new SLS lines being used.

Objective 3b: Compare the performance of the best subset of fungicide timings on tomato lines with & without EB/LB/SLS resistances. (a “research” component)

Overview: In years 2 and 3, the best products and timings from the year 1 trial will be used for testing on tomato lines and hybrids with triple-resistance at multiple locations. The tests will be conducted as in year 1 (split plot design) and subjected to statistical analysis. These tests will determine which combination of resistance (homozygous for LB and EB, either heterozygous or homozygous for SLS) and fungicide programs provides the best disease control.

Anticipated Impacts: By assessing the performance of resistant and susceptible tomato lines and hybrids under appropriate disease pressure and simultaneously evaluating 4 fungicide programs, we can assess the contribution of genetic resistance and the performance of approved fungicides. Should supplemental chemicals be necessary, we will have already evaluated a series of products for conventional or organic operations, with a range of EIQ levels. Further impacts are discussed in the Anticipated Impact Summary, below.

Objective 4: Field work in Albany/Columbia Cos. NY and in other VA, NC, and WV in Years 2 and 3 (“extension” component)

Overview: Plants will be characterized for horticultural characteristics in multiple locations in years 2 and 3. By growing in two different locations and over two seasons, we have a better opportunity for selecting material with the highest level of commercial acceptance and performance in two different operations. The best lines will again be field tested in wider regional trials. Trials will be conducted at locations with conventional and organic production over 4 states in two regions. The observations at these sites will guide the release of the tomato lines, or indicate what additional modifications of the lines are needed to gain acceptability.

Anticipated Impacts: It is important that new materials be trialed on the two farms selected for cooperation in NY. Both growers are keen observers and can aid in recommending the tomato lines that come closest for eventual release. The use of the wider regional trials is critical to broadly test the acceptability of the resistant lines/hybrids and the efficacy of their resistances. Extension cooperators will work with their grower networks to inform growers and to engage growers in research and trials as they are in process, and use trials as demonstration plots for field days (summer 2010 and 2011). Results will be presented at grower meetings cooperators routinely attend, and extension articles will be prepared and distributed (Capital District Newsletter, the Cornell Cooperative Extension Program of Central-Western NY Newsletter, Orange Co Muck and Mineral Newsletter, among others).

Objective 5: (a research component)

Overview: In years 2 and 3, the triple-resistant lines and hybrids will be used for replicated trials in organic production with a commercial line as a control. Plants and fruit will be characterized for horticultural characteristics in multiple organic locations in years 2 and 3 of the project. Trials will be conducted at least two locations with organic certification or production standards and scheduled IPM scouting. If necessary, fungicide programs will be implemented using data from Objective 3a above and OMRI approved products. The data from the plants and fruit grown at these sites will guide the release of the tomato lines and assist in developing recommendations for organic production with these disease resistance plants, or indicate what additional modifications of the lines will be necessary to gain acceptability.

Anticipated Impacts: Growing these new lines and hybrids at least two organic production locations over two seasons, will give the project team a better opportunity for determining if this material is successful under organic production systems and if the fruit meets commercial acceptance. One grower has been identified whom has a history of disease related problems growing tomatoes in her organically certified farm (see letter of support). She has hosted several trials at her farm and is capable of taking the necessary data and notes needed for this type of trial. A second organic grower will be recruited, but we will identify them in the first year of the program based on disease pressure on their farm. By assessing the performance of resistant and susceptible tomato lines and hybrids under organic production with natural disease pressure we can assess the contribution of genetic resistance for use in organic production of tomatoes. We will also utilize research from objective 3a if necessary on use of fungicide programs using OMRI approved products to evaluate the combination of genetic resistance and fungicide use, but only if necessary. Results will be published in research journals and newsletters and presented at organic and sustainable agriculture workshops and conferences. Further impacts are discussed in the **Anticipated Impact Summary**, below.

Anticipated Impact Summary for all Five Objectives Combined: Although the work to be accomplished in this project are separated into 5 objectives, to reflect the types of work and their locations, this project has one overarching objective: the coordinated control the three major defoliating diseases of tomato, EB/LB/SLS, through the use of resistance to each of the diseases combined with a IPM strategy combining the resistant varieties and minimal sprays of the lowest EIQ compounds where necessary to further support disease control (EB and SLS). Therefore, this project also has overarching impacts. The results of trialing with pesticides, in multiple regions that include the EB variant with resistance to strobilurins, will be immediately and directly applicable with current EB/LB resistant varieties (which have the same resistance as NC33EB1). This information will assist growers with decisions regarding effective fungicides with lowest EIQs and implementation of TOM-CAST, affecting a wide audience. The triple resistant tomato lines produced and released will enable seed companies to release triple resistant hybrids. Information on the relative control achieved with the best fungicide program and hybrids heterozygous vs. homozygous for SLS will inform the seed companies of how the SLS resistance must be present in the hybrids they sell (homozygous or heterozygous), providing growers with the best varieties for use. Combined, the work of the five objectives will encourage “science-based pest management that safeguards human health and the environment” because it will result in information and materials which, when combined, create a coordinated strategy for controlling the three diseases causing defoliation, and thereby loss of fruit yield and quality in

tomato throughout the NE to mid-Atlantic regions. This LB/EB/SLS control system would result in the use of the lowest number of fungicidal sprays per season and also the use of low EIQ fungicides, minimizing EIQ per season. The system would provide positive economic impact to growers through reductions in costs of sprays, and in reductions in risk of crop loss. The system would also impact the “implementation of IPM”, since use of the system that covers all three defoliating diseases will be manageable rather than using separate IPM programs for LB and EB and SLS. In all, the proper use of the SLS/EB/LB hybrids in the IPM system for all three diseases will reduce reliance on and use of chemical controls, shift chemicals used to those with lower EIQs, reduce costs of production for growers, reduce risk associated with pesticide usage for agricultural workers and the environment, as well as risk of pesticide residue for consumers.

This project could also have further impacts on other crops and for other diseases, by providing a model that could be used in work on disease control in other crops. Typically breeding and work in field plant pathology targets a single disease. In contrast, this project demonstrates the need to target a cluster of diseases when they cause similar issues (defoliation of tomatoes) and illustrates the opportunities to be seized for coordinated control. In addition, it is typical for breeding for resistance and work by pathologists and extension specialists on other means of disease control to proceed separately, leading to considerable inefficiency. A resistance gene that does not, in itself, provide full control of the disease may be overlooked by the breeder, rather than consider that the combination of this resistance plus a mild control could provide impressive control. Similarly, pathologists and extension specialists may develop methods and test compounds for disease control on standard cultivars, unaware of resistant materials in development, to find that their work is obsolete, or at least incomplete, upon the release of the resistant material. The coordination of breeding and pathology/extension efforts to create combined strategies, as illustrated by this project, will be the most cost and time effective means of dealing with crop diseases. Hopefully the success of this project can stimulate the adoption of similar coordinated work for other crops and diseases.

iii. APPROACH AND PROCEDURES WITH PROJECT TIMETABLE (Table 2 below)

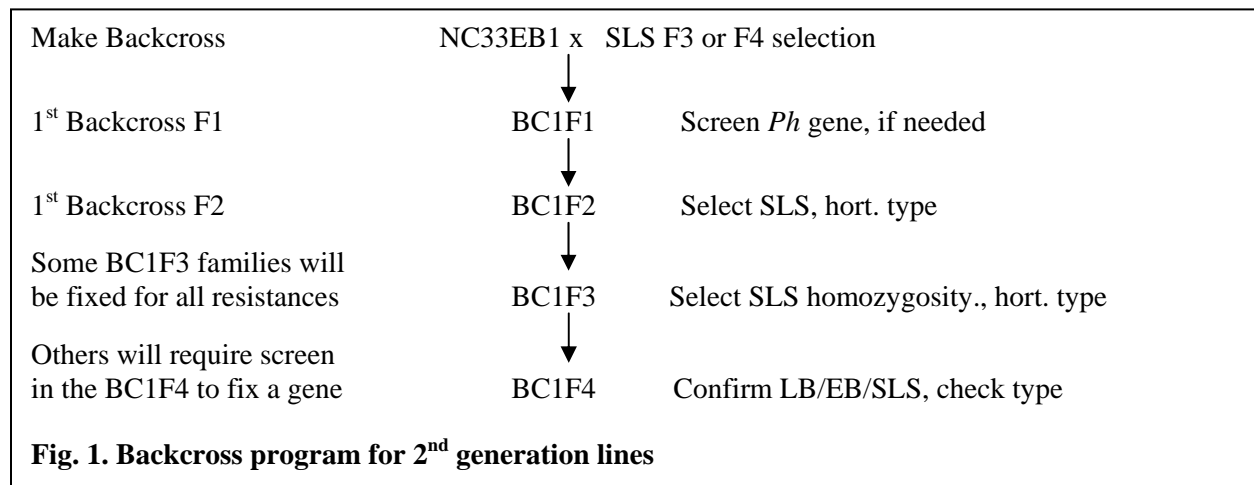
Objective 1: Combine SLS resistance with LB and EB resistance in high quality tomato line.
 (“research” component)

Plant materials for starting this objective. The breeding program has already started the process of combining LB, EB, and SLS resistance. This began with the testing of the EB/LB x SLS hybrid NC33EB-1 x 071733-1 and its F2 progeny in a field SLS screen in summer, 2008. That work included the selection of SLS F2 plants with the best plant/fruit type, and subsequent screening their F3 progeny fall 2008 to isolate that subset of F3 progenies homozygous for SLS. Work is continuing to evaluate these selections. In late spring 2009, we will have established which SLS F3 progenies also possess LB and EB, and will have selected, if necessary, to isolate progeny plants homozygous for the LB genes *Ph2* and *Ph3*. This will have established a series of F3 & F4 lines homozygous for LB and SLS for use when this project starts summer of 2009. There may also be some F3 & F4 lines homozygous for SLS, but segregating for either *Ph2* or *Ph3*. Those lines could still be used, since we can select only the SLS homozygous plants for transplantation by marker analysis at the seedling stage, before they are transplanted in the field.

Approach. This objective will proceed to develop two types of lines LB/EB/SLS, in case one type of line proves superior to the other. The first set of lines (first generation lines) are derived

without any additional backcrossing, the second set of lines (second generation lines) will use one additional backcross to NC33EB1. First generation lines will be well advanced by the time this project begins summer of 2009, due to the work completed as described above. The additional work summer of year 1 will finalize testing for the three resistances, and provide the data on the horticultural type of the lines being created. Selection for uniformity of desirable plant type is used to reduce the number of selection and obtain the characteristics desired.

The 2nd generation lines will be developed using a standard, backcross program performed as shown in Fig. 1. Since the F3 or F4 line being used in the backcross will already carry LB and EB resistance, only SLS screens will be required in the backcross generations. However, if the LB/SLS lines with the best plant and fruit type are found to NOT be fixed for EB, it would still be as or even more effective to use the backcross method to select for homozygous EB lines, since the EB gene is present in the backcross parent NC33EB1. The only difference is that EB screens would be needed as well as SLS in the BC1F2 and BC1F3 generations. Again, selection for uniformity of desirable plant type is used to obtain the characteristics desired.



Procedures. This work uses a combination of seed handling techniques, horticultural techniques, molecular techniques and disease screens to advance the breeding populations. With careful planning, three generations of tomato can be handled per year. To produce crosses (hybrid) seed, tomato crosses are made using manual emasculation of flower buds on female plant, and pollination of emasculated buds with pollen from the male parent. Tomatoes are naturally self pollinating, so allowing the plants to set self fruit and collecting the seed produces any selfed generation needed.

Screening for resistance genes directly or by response is a critical process in this objective. We screen young plants for SLS resistance under controlled conditions in misting chambers (Poysa and Tu, 1993), with inoculum preparation and concentration as described by Tu and Poysa (1990). Field SLS screens are performed using the same inoculum, with irrigation used before and after inoculation to provide conditions conducive for disease development. The SLS gene is not yet mapped, so no marker is available. The presence/homozygosity for the LB gene *Ph3* is determined using PCR based marker for *Ph3* (Mutschler et al, unpub.). We have screened for *Ph2* using RFLP and linked markers (TG233), but will be converted to PCR. Since the *Ph2/Ph3* combination provides sufficient resistance without sprays, direct disease screens for late blight

are not needed to advance this program. Since the EB gene is not mapped, no marker is available. We screen young plants for EB using the greenhouse stem puncture technique of Gardner (1990), and screen for EB in the field as described in Zitter et al (2005).

To establish a field screen for one or more segregating population, seed is sown (including controls) in late April, and transplanted to the field in June, using a RCBD, typically with 3 or 4 replications of 5-plant plots for controls. Maximum size is used for the segregating populations (which is at least 100 plants, preferably 300 or more, since larger populations allow tighter selection for plant and fruit characteristics). A field screen for a segregating population is generally performed to screen for those plants possessing a trait in an early generation; plants in a segregating population are expected to show differences rather than uniformity. A field screen comparing lines to controls would be sown and transplanted on a similar schedule, and would use a RCBD, typically with 3 or 4 replications of 5-plant plots for both lines and controls. Tests of lines vs. controls are generally in more advanced generations, for tests of homozygosity of resistance, uniformity of type.

Objective 2: Testing disease response and horticultural type in triple-resistant lines and hybrids. (“research” component)

Approach. There is a need for service trials for disease or for horticultural type in years 1 and 2, to support the breeding work in Objective 1 or the trials of spray program or production systems tested in Objectives 3 to 5. For example, each generation of a breeding program generates far more resistant plant than one can advance to the next generation; 25% of an F2 population is expected to be fixed for a single segregating gene. It is advisable to progeny test when one has selected on a single plant basis, increasing the numbers of plants to be handled. Therefore additional trials/measurements of quality are used, in addition to disease resistance, to select for the best subset of selections to advance to the next breeding cycle. Similarly, the trials in Objectives 3 to 5 must, by their nature, be limited in the number of lines they contain; testing a series of compound on a large number of lines would create an experiment that is too large. Therefore it is necessary to pretest the available lines and hybrids as they are produced, to determine which should be used for the tests in Objectives 3 to 5.

Procedures. We will evaluate all of the first generation candidate lines, and appropriate controls in a field trial in Ithaca in two trials, one with SLS pressure and the other with EB pressure as described in Objective 1. We will also examine horticultural type in the both of the trials. Plants will be seeded in late April, and transplanted to the field in early June. Trials will consist of RCBD with 4 reps and 2 rows of 5 plants per genotype per rep. The ratings for fruit size and quality characteristics will be determined in mid/late August (when early varieties are approximately more than 75% ripe, and main season varieties are approximately 50%). This will allow selection of lines to use in wider tests in summer of 2010, and for the best selections for use in producing hybrid seed winter of 2009/2010 for use in objectives 3 to 5. The first year trials will also increase seed to provide materials for the regional trials in year 2 and 3. Similar test will be performed in year 2 (2010) on more advanced lines, again to select the best materials for use in Objectives 3 to 5.

Objective 3a: Determining the efficacy of four fungicide treatments (a reduced spray schedule, TOM-CAST-18 and TOM-CAST-25 and an organic treatment) for the control of SLS with or without genetic resistance. Summer 2009. (“research” component)

Approach. For this objective, we will test four fungicide programs to establish their effectiveness in combination with the genetic resistances available. The four tomato entries used for all 4 programs will include NC33EB-1 (the EB/LB resistant, SLS susceptible line), and three of the new first generation SLS lines being selected in the screens being completed winter of 2008 (See overview to Objective 1 above). The 4 fungicide programs (plus an unsprayed control) will consist of: 1) OMRI-listed products (Serenade + basic copper sulfate); 2) and 3) are two programs utilizing TOM-CAST = environmental monitoring initiated 2 weeks after transplanting, with first fungicide applied in program 2 when the cumulative daily disease-severity values (DSV) reached 18 or in program 3 when 25 DSV are reached; and 4) a conventional program with fungicides applied on a 14 day schedule. For the conventional fungicide program (2, 3 and 4), Quadris Top (azoxystrobin + difenoconazole) will be alternated with Bravo (chlorothalonil), as work in 2008 showed this to be the best treatment for both EB and SLS, avoided fungicide resistance, and had a good reduction in EIQ values (Zitter & Drennan 2009a, b). A water control will also be included. This trial of four programs, will allow us to test the most likely fungicide programs to deal with the fungicide resistance issue and programs that are most likely to be adopted by conventional and organic growers. This trial is limited to use of homozygous SLS resistance, because it permits screening more lines, and since a spray program that is insufficient for homozygous resistance must be insufficient for heterozygous resistance as well.

Procedures. The four fungicide treatments and programs plus an unsprayed control will be arranged in a split-plot design with fungicide application schedule as the whole plot and the 4 tomato lines/hybrids as the subplot nested within each block and replicated four times. Each block will consist of 4 rows, one for each line/variety, with each containing 8 plants spaced 24 in apart within a 15ft row. All plots will be inoculated with SLS and overhead irrigation applied as needed. Treatments will be applied with a pressurized boom sprayer. Disease assessments for SLS will be made weekly (Horsfall-Barratt rating, 0-11 scale). Foliar data will be converted using the area under the disease progress curve (AUDPC) model to account for foliar disease progression over time. Separate ratings will be taken on stem (0-5 scale) since this is another measure of disease resistance for SLS. Results will be subjected to statistical analysis.

Objective 3b: Compare the performance of the best subset of fungicide timings on tomato lines with & without EB/LB/SLS resistances, summer 2010, 2011. (“research” component)

Approach. In years 2 and 3, the best fungicide timings from the Objective 3a will be used for testing a SLS tomato line, its hybrid and control with triple-resistance selected from the materials selected from in year 1 Objective 1 and 2. The tests in Objective 3b will determine which combination of resistance (homozygous for LB and EB, either heterozygous or homozygous for SLS) and fungicide materials and schedule (selected from a 14 day schedule, TOM-CAST-18 or TOM-CAST -25, and organic) provides best disease control.

Procedures. The tests in years 2 and 3 will be conducted as in year 1 (split plot design) and will be subjected to statistical analysis. The tests will be performed at three locations (NY, VA, &

NC) to subject the cultivars and fungicide schedules to a wide range of environmental conditions. The plant materials used in year 2 will be NC33EB-1 (the EB/LB resistant, SLS susceptible line), the best first generation line homozygous for all three resistances from year 1, and the hybrid created by crossing that line with NC33EB1. The tests will again be performed in research plots, utilizing EB and SLS inoculations. Plant material used in year three will include new hybrids created using the best LB/EB/SLS lines created in Objective 1. These hybrids could be homozygous for LB & EB and heterozygous for SLS, or homozygous for all three resistances.

Objective 4: Field work in Albany/Columbia Cos. NY in Years 2 and 3 summer 2010, 2011, (“extension” component)

Approach. Plants will be characterized for disease response, if it occurs naturally, and for horticultural characteristics in multiple locations in years 2 and 3. The best cultivars will again be field tested in wider regional trials. The number of entries per location will depend on the space available at each location. Trials will be conducted at two locations in NY, one with conventional production and the other on an organic farm, containing the same entries, plot design and evaluation used. Plant material used in year 2 will be selected based upon the results of field trials in Objectives 3a above. Plant material used in year 3 will include new hybrids created using the new LB/EB/SLS lines created in Objective 2 above. These hybrids could be homozygous for LB and EB, and heterozygous for SLS, or homozygous for all three resistances.

Procedures. The personnel at these locations are experienced with running these types of trials (Previous NEIPM grant). No difficulties are expected, other than the uncertainty with any field trial as to whether the weather conditions that year will be favorable. The TOM-CAST data for the area will be recorded to see pressure during the trial, but these trials will not be inoculated, but will allow us to assess horticultural characteristics (any flaws to correct).

Objective 5. Organic field work in West Virginia in Years 2 and 3 summer 2010 and 2011, (“research” component)

Approach. Plants will be characterized for disease response, if it occurs naturally, and for horticultural characteristics in two organic farmer/grower locations in years 2 and 3. The best cultivars will again be field tested in a second year with organic fungicide treatments if necessary. The number of entries per location will depend on the space available at each location. Trials will be conducted at two organic field sites in WV, containing the same entries, plot design and evaluation used. Plant material used in year 2 will be selected based upon the results of field trials in Objectives 3a above. Plant material used in year 3 will include new hybrids created using the new LB/EB/SLS lines created in Objective 2 above. These hybrids could be homozygous for LB and EB, and heterozygous for SLS, or homozygous for all three resistances.

Procedures. The WV PD and growers at these locations are experienced with running these types of trials (Previous USDA grant subaward). No difficulties are expected, other than the uncertainty with any field trial as to whether the weather conditions that year will be favorable. The weather and TOM-CAST data for the area will be recorded to see pressure during the trial, but these trials will not be inoculated, but will allow us to assess horticultural characteristics (any flaws to correct).

Table 2 Project Timetable

Objective	Leader	Year	Goal	Work Period	Completed
<i>Objective 1</i> Combine SLS resistance with LB and EB resistance in high quality tomato line	Mutschler	1	Determine the SLS lines with the best horticultural type, select for type, uniformity.	June '09 to Sept. '09	Oct. '09
		2	In fall 09 create hybrid seed for use in summer '10, obj. 1, 2, 3, 4. In winter '09/10	Nov. '09 to Sept. '10	Oct. '10
		3	In fall '10 create hybrid seed for use in summer '11 obj. 1, 2, 3, 4.	Nov. '10 to Sept. '11	Oct. '11
<i>Objective 2</i> Testing disease response and horticultural type in triple-resistant lines and hybrids	Mutschler and Zitter	1	Determine the SLS lines with the best SLS/EB response	June '09 to Sept. '09	Oct. '09
		2	Compare horticultural type of best SLS lines, and hybrids of SLS lines with that of control, select subset to advance.	Nov. '09 to Sept. '10	Oct. '10
		3	Full horticultural analysis of best SLS lines and hybrids, determination of lines to release to seed companies, present at Field Day meeting with company reps.	Nov. '10 to Sept. '11	Oct. '11
<i>Objective 3a:</i> Determining the efficacy of 4 fungicide treatments for control of SLS with or without genetic resistance	Zitter	1	Test NC33EB-1 (SLS susceptible) and three new SLS resistant lines with 14 day schedule, TOM-CAST -18, -25, OMRI approved materials & unsprayed control, inoc. SLS to determine the best treatment to supplement SLS resistance	June to Sept '09	Nov. '09
<i>Objective 3b:</i> Compare the performance of the best subset of fungicide timings for control of SLS and EB on tomato lines without, heterozygous or homozygous SLS, homozygous for EB	Zitter, Rideout, Ivors	2	Determine which combination of resistance (homozygous for EB, and either heterozygous or homozygous for SLS) and select fungicide programs (+ unsprayed control) providing the best disease control, inoc. with EB,SLS (in NY) and natural occurrence in VA and NC.	June to Sept. '10	Nov. '10
		3	Trial newest SLS/LB/EB hybrids & parental lines with same select fungicide programs (+ control) inoc. with EB & SLS in NY and natural occurrence in VA and NC.	June to Sept. '11	Nov. '11
Objective 4. Field work Albany (Conventional)/ Columbia (Organic) Cos., Years 2 and 3	Born	2	Trial SLS/LB/EB hybrids and & susceptible Std cultivars (natural inoculum).	May to Oct. '10	Nov. '10
		3	Expanded trials of SLS/LB/EB lines and newest hybrids (natural inoculum).	May to Sept. '11	Nov. '11
Objective 5	Liedl	2	Trial SLS/LB/EB hybrids (natural inoculum) in coop with organic growers.	May to Oct. '10	Nov. '10
		3	Expanded organic trials of SLS/LB/EB lines and newest hybrids (natural inoculum).	May to Sept. '11	Nov. '11

(iv) Evaluation Plans. (Table 3 below)

This project will have a profound influence on both conventional and organic growers in several ways. First the project will introduce the use of multiple disease resistant tomato lines and hybrids to all grower groups, something that was not previously available for the disease(s) most often encountered. Second we need to evaluate the performance of currently used chemicals for disease control and what chemicals (including OMRI listed products) the grower might consider using based upon the results of this project. We will be utilizing TOM-CAST in conjunction with genetic resistance and demonstrate how fungicide sprays can be eliminated.

Getting measurable data on these objectives can be achieved by the project participants developing grower surveys in the early stages of the project using a survey in Table 3. We plan to present our questionnaire and findings of our results at the annual vegetable meetings: the Fruit and Vegetable Expo held in Syracuse, NY, the Mid-Atlantic Fruit and Vegetable conventions in Hershey, PA; the Long Island Forum at Riverhead, NY, the Vegetable Growers Association in Atlantic City, NJ; the Fresh Market Vegetable Meeting in Lockport, NY, and the New England Vegetable and Berry Conference in Manchester, NH. We will also take advantage of twilight meetings (both traditional and organic) that we (Zitter, Bornt) participate in various countries during the summer (Orange, Ulster, Dutchess, Columbia, Albany, and Eden Valley). The major contact for the organic growers will be through the NOFA meetings.

In the past we have held twilight meetings at both of our cooperators farms (Courtens and Stanton), and we plan to do the same during the course of this project. This will give us the opportunity to show the resistant tomato varieties to a wide audience, at which time we can distribute the current questionnaire and gain advice in the early stages of the project.

Another survey will be conducted with grower (some of the same) at the end of the project to determine how much they have learned and how this project has influenced their management practices. The majority of our results will be posted on the Vegetable MD web site that is maintained in the Department of Plant Pathology in Ithaca (Zitter). To monitor the impact that extension articles has on the growing public, we will monitor the number of hits received on this web site for specific fact sheets and a specific organic segment to be added. The site currently receives over 1 million hits per year, so it is well known resource to a wide audience.

One of the participants (Bornt) will publicize the project results on his own grower newsletter. This will built more interest in the project and may encourage more grower participation even beyond the life of the project.

Plant breeding is an important component of this project. Yearly updates will be provided to private breeders at the yearly vegetable breeding field day (last Monday and Tuesday in August) and in annual vegetable breeding reports. Reports are forwarded to public and private tomato breeders through the Reports of the Tomato Breeders Roundtable. Tomato lines developed by the project director (Mutschler) will be made available to other breeders at both public and private institutions for broader dissemination of genetic resistance in tomato. A tally will be maintained of the requests for breeding materials.

Table 3 Draft of survey:

1. If you currently grow tomatoes, are you traditional or organic?
2. List the top 3 or 5 varieties you grow, whether hybrid or heirloom. Do you know the level of disease resistance?
3. Assuming you have disease problems, circle all that apply on your farm:
early blight, late blight, Septoria leaf blight, or don't know.
4. What fungicides do you currently use for disease control?
If conventional, circle those that apply: chlorothalonil (like Bravo); strobilurin (Group 11) (like Quadris, Cabrio, Flint, Tanos); fixed copper (like Champ or Kocide); maneb or mancozeb (Maneb or Manzate or similar products); late blight specific materials (like Curzate, Previcur Flex, Forum, Gavel, Ranman, Presidio, others _____)
If organic, circle those that apply: botanical oils (like Sporan, Neem); basic copper sulfate; biologicals like Serenade™ or Sonata™; potassium bicarbonate (like Armicarb or Milstop), or others_____.
5. Have you heard about the TOM-CAST program with environmental monitoring to determine when sprays should be applied? _____. Would you be interested in learning more to reduce the number of fungicide sprays?_____
6. How do you feel the products you applied controlled disease? (very good, some, very little) Have you experienced any failures? _____. Are you aware of fungicide resistance for Alternaria EB with Group 11 fungicides? _____.
7. How often did you have to spray your current tomato crop?_____ Every 7 or 14 days; other schedule?
8. Do you begin spraying based upon 1) when disease first appears; 2) at a particular crop growth stage, i.e. when fruit are developing; 3) when a newsletter alerts me to spray; 5) when disease severity values accumulate (ie. TOM-CAST); 4) I don't spray?
9. Do you feel you have enough information about resistant tomato varieties?
10. Would you consider growing multiple disease resistant hybrid varieties on your farm? Yes or No. What data would you need to see to make a decision?
11. If better controls were available for foliar blight diseases, would you consider trying alternatives? Yes or No
12. If more environmentally friendly materials were available that were as effective as synthetic pesticides, would you consider using them as part of disease management? Yes, no, always, sometimes, or never.
13. How important is an Internet web site for learning about disease control measures and the use of resistant varieties? Yes, no, always, sometimes, or never.
14. Any comments you can add for the good of the project?

(v) Key Personnel

New York: Cornell University and Cornell Cooperative Extension

Martha A. Mutschler, Dept. of Plant Breeding & Genetics, CALS, Cornell .

PD for Objective 1, and co PD for objective 2

Interacts with PD/cooperators at other sites, providing seed materials and information supporting Objectives 3, 4, and 5

Thomas A Zitter, Dept. of Plant Pathology & Plant-Microbe Biology, CALS, Cornell.

PD for Objective 3, and co PD for Objective 2

Interacts with PD/cooperators at other sites, providing information supporting Objectives 4, and 5

Charles Bornt, Capital District Vegetable Program, Cornell Coop. Extension. Troy, NY

Cooperator interacting with Zitter and Mutschler on Objective 4, working with two grower participants Jean-Paul Courtens (organic grower, 1,000 CSA clients, see letter) and Tim Stanton (conventional grower sing field and high tunnel, see letter)

West Virginia, West Virginia State University, Institute, WV

B E. Liedl, , Gus R. Douglass Land-Grant Inst., WVSU

PD-Coop. for Objective 5, directly interacting with Mutschler, working with grower participants. Participants are Schaer (organic grower, see letter) and one other to be identified from list of participants in prior project with Liedl.

Virginia: Virginia Tech Univ., Eastern Shore AREC, Painter, VA

Steven L. Rideout,

Coop. for Objective 3 for the Virginia sites, directly interacting with Zitter

North Carolina: NCSU, Mt. Hort. Crops Res. & Ext. Ctr., Fletcher, NC

Kelly L. Ivors,

Coop. for Objective 3 for the North Carolina sites, directly interacting with Zitter

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Relevance Statement for Projects Submitted to the NE-IPM Program for 2008

(a) Names of Institutions of PDs and major cooperators:

New York: Cornell University and Cornell Cooperative Extension

PD - Martha A. Mutschler, Dept. of Plant Breeding & Genetics, CALS, Cornell .

PD - Thomas A Zitter, Dept. of Plant Pathology & Plant-Microbe Biology, CALS, Cornell.

Charles Bornt, Capital District Vegetable Program, Cornell Coop. Extension. Troy, NY

West Virginia: PD-Coop. B E. Liedl, Gus R. Douglass Land-Grant Inst., WVSU, Institute, WV

Virginia: Virginia Tech Univ., Coop. - Steven L. Rideout, Eastern Shore AREC, Painter, VA

North Carolina: NCSU Coop. - Kelly L. Ivors, Mt. Hort. Crops Res. & Ext. Ctr., Fletcher, NC

(b) Title: Combined Resistance to Late Blight, Early Blight, and Septoria Leaf Spot in Tomato, and Complementary Fungicides for NE and other Temperate Production Regions

(c) Project Type: Joint Research-Extension

(d) Project summary This Research & Extension project (\$164,249 PL89-106, \$10,720 Smith-Lever) targets improved control, with reduced pesticide load, of early blight (EB), late blight (LB), and Septoria leaf spot (SLS), the 3 main fungal diseases of tomatoes in the eastern US. These diseases occur in all NE states to the Southern region and are repeatedly listed as priority items. Another priority is strobilurin resistance found in EB isolates in NY, NC. This project unites breeders, pathologists, horticulturists, and conventional & organic growers in 4 states and two regions to meet priorities by developing LB/EB/SLS resistant tomatoes (adding SLS resistance to a LB/EB resistant line), and testing disease response of these lines with reduced sprays of low EIQ fungicides. Severe SLS damage across the NE in 2008 demonstrates the need for this resistance. We address strobilurin resistance by selecting appropriate replacements, scheduling use (TOM-CAST), and assess how reduced sprays and plant resistance can improve control and reduce grower costs. Conventional and organic grower-cooperators will serve as multipliers. The objectives are: 1 & 2) Combine SLS, LB and EB resistance in elite tomato lines, testing disease response and horticultural; 3 a & b) Determine efficacy of four fungicide treatments for disease control with & without genetic resistance (NY) then compare the best timings on lines with & without EB/LB/SLS resistances (NY, VA and NC); 4&5) Test EB/LB/SLS lines and hybrids in multiple sites (NY, WV) for control and horticultural properties. This project covers the priorities listed in NE-IPM RFP, and explained in the **Justification**.

(e) Problem, Background and Justification

Problem. This project addresses control of LB, EB & SLS in tomatoes in New England (6 states), Northeast (NE: NJ, NY, PA), mid-Atlantic (VA, NC), North Central (MI, IN, OH). Combining NJ, NY, PA VA and NC, 2007 tomato acreage was 16,600A, valued at *ca* \$187 million (USDA Statistics, 2007). Disease control is a major concern in these regions; many fungicide sprays are used to protect yields & quality. Dominant disease varies with years; SLS was devastating in many areas in 2008. Emerging issues include strobilurin- resistant EB isolates and severe SLS in LB/EB resistant tomatoes grown with minimal fungicide. This could greatly increase reliance on protectant fungicides and increase the number of sprays used. Excessive spraying is undesirable for growers, due to increased costs, to the environment and rural community due to increased compound release, and for consumers, due to risks of residuals.

Background. LB, EB, & SLS are repeatedly identified as significant problems by tomato growers in New England, Northeast (NE), and mid-Atlantic states. Grower surveys conducted in New England states starting in 2002 (Anon. 2002) and prioritized as IPM Needs for the NE (2003-2007) showed how critical these three diseases are across the region. (http://northeastipm.org/work_vegpriority2007.cfm), The 2007 Pest Management Strategic Plan for tomato compiled for VA, NC and DE identified the same three diseases. (<http://www.ipmcenters.org/pmsp/pdf/SRTomato.pdf>). These concerns are echoed in letters from extension specialists NY (Born, Mishanec, Hadad, and Reid), VT (Hazelrigg), PA (Gugino) and the NC Tomato Growers Assoc. (Sprague). Some reductions in sprays were achieved using the TOM-CAST (EB, SLS), or Blitecast (LB) forecasting systems, but EB/ LB varieties were released after these systems were created and tested. In a previously funded NEIPM grant (Mutschler & Zitter 2005) LB/EB resistant lines were created, and trials of these lines demonstrated that optimal control of EB is obtained by growing LB/EB varieties in combination with minimal sprays of strobilurins, coppers or biologicals. EB/LB resistant varieties are now being sold by seed companies based on lines from the public breeding programs at NCSU and Cornell. However, trials also showed that growing EB/LB varieties with minimal fungicides results in severe SLS (Mutschler & Zitter, 2005), an emerging issue for growers. This project will add SLS resistance to the elite LB/EB line (a rapid process). Another recent development is the appearance of EB isolate resistant to the strobilurin fungicides favored for EB control. Fungicide resistance has already been identified in tomato in 2 states (NY and NC, Zitter and Ivors, respectively), and is expected to be widespread. However, excellent control was achieved in field studies in 2008 using fungicide replacements for azoxystrobin in conjunction with the most advanced EB/LB hybrid (NC06115). Without advancement of this project we could see a dramatically increase the number of fungicide sprays and a stronger reliance on protectant fungicides. With completion of LB/EB/SLS lines, and the testing of disease control in these resistant lines with/without supplemental fungicides with low EIQs (Environmental Impact Quotients) while following TOM-CAST forecasts, we can make accurate recommendations for controlling LB, EB, & SLS across wide areas with different levels of disease pressure, and in both traditional/organic production.

Justification. Since tomato is one of the most popular and widely grown vegetables across many regions, there is great opportunity to reduce fungicide usage. Current technologies/ practices for EB, LB, SLS control in tomato are inadequate, using excessive amounts of higher EIQ compounds and still failing to adequately control these three foliar diseases. Part of our strategy to solve these problems is the development of LB/EB/SLS resistant varieties, using LB/EB and SLS lines already created. Since the resistance to EB, and possibly also that to SLS, does not provide fully protection, the second part of the strategy is to determine the best low EIQ sprays to supplement the disease control provided by resistance. Treatments will be applied using a reduced spray schedule, using TOM-CAST, and test OMRI-listed products. This project covers all of the 14 priorities in the RFP for NE-IPM (Table 1). By working with both conventional/organic growers, selecting growers who are proven innovators and willing to extend their knowledge to other growers, we will attract the largest audience for adoption of our findings. Our cooperators in WV, VA and NC will also be performing similar trials working with growers in their area, since using wider regional trials is critical to broadly test the acceptability of the resistant lines/hybrids and efficacy of the programs/compounds to maximize control of EB & SLS. Another set of stakeholders are the seed companies, who produce/sell seed for new tomato varieties to growers. Seed companies readily accepted LB/EB, resulting in recent LB/EB

hybrids. Companies are interested in the EB/LB/SLS lines in development. By providing companies with access to triple resistant tomato lines, and information on how to use them, enables them to make a series of resistant hybrid varieties available to growers. It is a win-win interaction that provides the greatest benefit to all.

Table 1. The priorities of the NE-IPM program covered by this program

1. Will reduce environmental risks through reducing reliance on pesticides for control of EB/LB/SLS and determining supplementary pesticides with the lowest EIQ that complement LB/EB/SLS lines.
2. Will reduce risks to human health through supporting tomato production with minimal risk of pesticide residue, including supporting organic production of tomatoes.
3. Has stakeholder support: support and priority as cited in the background above.
4. Focused on a pest/crop in at least five states/ cropping regions: since LB/EB/SLS are problems of tomato production in nearly all of the NE states, plus NY, PA, NJ, NC, VA, & Midwest (OH, IN MI).
5. Will fill a unfilled niche since the project addresses the need for new SLS resistance and for alternate low EIQ strategies for new strobilurin resistant <i>Alternaria</i> strains.
6. Involves three or more states in an active partnership, including in NY, WV, VA and NC.
7. Will advance IPM soon; spray trials results immediately useful for current LB/EB hybrids. Variety release can be rapid. Work from 2005 NE-IPM grant contributed to current LB and LB/EB hybrids.
8. Is interdisciplinary, involving a plant breeder, plant pathologists, and extension specialists.
9. Reduces dependency on chemical pesticides through use of triple disease resistance supplemented with minimal sprays (TOM-CAST) with low EIQ compounds.
10. Has significant economic implications: reduce cost of disease control for all growers in the regions.
11. Serves an "underserved audience": involved active cooperation 1890 land-grant institution and it's organic growers participants
12. Addresses emerging problems, specifically of the need to control SLS in new varieties resistant to EB and LB and to address control of strobilurin resistance <i>Alternaria</i> strains.
13. Results are will be adopted by the target audience: seed companies already LB/EB lines, and have requested SLS lines, grower indicate high priority LB/EB/SLS control and are involved in project.
14. Advances a more cost-effective IPM practice: use of a resistant variety imposes little extra costs, done very easily; reduction in the number of sprays reduce costs of disease control.

(f) Project Objectives and Anticipated Outcomes

Obj. 1. Combine SLS, LB & EB resistances in high quality tomato line (research); Outcome: Development of SLS/EB/LB resistant tomato lines with good type and adaptation to regions. .

Obj. 2. Testing disease response and horticultural type in SLS/EB/LB resistant lines and hybrids. (research); Outcome: This objective generate data & produces seed in support of obj. 1, 3, 4 & 5.

Obj. 3a & 3b. Determining the efficacy of 4 fungicide treatments for EB & SLS control with & without genetic resistance (NY, VA, NC), (research); Outcomes: By evaluating 4 fungicide programs (reduced sprays, TOM-CAST-18 and -25 and organic treatment), then testing a subset of timings with/without EB/LB/SLS lines, we can assess the contributions of resistance and approved fungicides, showing if supplemental chemicals are needed, and which to use.

Obj. 4. Field work in Albany/Columbia Cos. NY in Years 2 and 3 (extension); Outcome: By growing in different locations and over two seasons, we select best material for commercial acceptance and performance in conventional and organic settings.

Obj. 5. Field work in WV, Years 2 & 3 (research); Outcome: By growing in organic fields over two seasons, we select best material for commercial organic acceptance and performance.