CPS CENTER for PRODUCE SAFETY

CPS 2010 RFP
FINAL PROJECT REPORT

Project Title
Irrigation regime, fruit water congestion and produce safety: parameter optimization to reduce susceptibility of tomatoes and peppers to post-harvest contamination, pathogen transfer and proliferation of *Salmonella*

Project Period
January 1, 2010 – December 31, 2012

Principal Investigator
Max Teplitski
University of Florida
maxtep@ufl.edu, 352-273-8189

Co-Principal Investigator
Jerry Bartz, University of Florida
George Hochmuth, University of Florida

Objectives
1. To reduce post-harvest susceptibility of tomatoes and peppers to *Salmonella* through the optimization of irrigation regime and fruit wetness at harvest With this objective, we will test how differences in physical properties of the fruit resulting from different irrigation regimes pre-harvest and fruit wetness at harvest will affect susceptibility of fruit to contamination with *Salmonella* from rubber gloves and/or wiping cloths.

2. To determine whether water congestion (with or without post-harvest soft rot or sour rot decay) is a risk factor for *Salmonella* colonization or internalization. In the field, congestive water in fruits may result from root uptake, rainfall, saturated atmospheres or harvest-related injuries. Experiments proposed here will determine whether fruit water congestion with or without postharvest decay is a risk factor for *Salmonella* contamination and/or internalization in tomato and pepper tissues under the simulated production line conditions. We will compare survival of *Salmonella* in water-congested fruit at three stages of ripeness (green commercial harvest, breaker/pink (commercial vine-ripe) or fully red). Because water congestion is known to predispose produce to infections with plant pathogens, and because soft-rot pectobacteria and sour rot yeasts are known to promote growth of *Salmonella* in fruit tissues under laboratory conditions, we will test how these two factors affect proliferation of *Salmonella* in tomatoes and peppers post-harvest.

3. To define the role for spoilage bacteria in contamination of fruit with *Salmonella*. In soft rots caused by pectobacteria, Salmonella grows to final populations that are 10-100x higher than in mechanically damaged fruit. It is not yet known whether plant pathogens, when present at low numbers, will also promote contamination of produce with *Salmonella*. We will determine the mechanisms by which two common plant pathogens of tomato and pepper promote susceptibility of fruit to contamination and internalization of *Salmonella*.

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FINAL REPORT

Abstract
The direct and indirect effects of the irrigation regime on post-harvest susceptibility of tomatoes and peppers to *Salmonella* were tested in three field seasons conducted in two locations in Florida (North and Central Florida). The most important discovery is that there were dramatic differences in susceptibility to *Salmonella* depending on the maturity stage of the picked fruit. Tomatoes at USDA ripening stage 6 were significantly more susceptible to *Salmonella*. Peppers were generally more susceptible to infections with *Salmonella* than tomatoes. The irrigation regime per se had only modest and not statistically significant effect on the susceptibility of the fruit to post-harvest infections with *Salmonella*. The presence of soft rots or lesions caused by *Xanthomonas* and/or *Pseudomonas spp* significantly promoted proliferation of *Salmonella* in fruit, but tomatoes without obvious signs of disease picked from plants showing signs of phytopathology elsewhere were not any more susceptible to *Salmonella*.

Background
It is clear that *Salmonella* and other human pathogens can contaminate produce at any stage of the production cycle, farm to fork. However, outbreaks of produce-associated gastrointestinal illness caused by non-typhoidal *Salmonella* and *E. coli* EHEC O157:H7 have been sporadic. The seemingly random nature of the outbreaks argues for the possibility that some event(s) during the production cycle make vegetables more susceptible to contamination with enteric pathogens from various environmental sources. For example, chilling or physical injury, leaf margin scorch, the presence of plant pathogenic bacteria and fungi have all been shown to increase susceptibility of produce to contamination with human enteric pathogens from various environmental sources. These observations lead to two general models to correlate field contamination of tomato fruit by *Salmonella* with subsequent multistate outbreaks of salmonellosis. In the first model, human pathogens are introduced onto plants where protected and/or favorable niches enable survival and multiplication. The pathogen subsequently spreads to fruit surfaces where injury, decay, and mishandling before, during, and/or after harvest enable the development of populations needed to infect humans. In the second model, as a result of a contamination event from any of various natural sources, *Salmonella* multiplies within produce that has experiences a massive loss of resistance to general saprophytes.

Fruit water congestion and fruit wetness as potential factors in fruit contamination with enterics. The most likely environmental event leading to a loss of tissue resistance occurs when water floods intercellular spaces in fruit tissues. However, the role of fruit tissue water congestion or fruit wetness in microbiological safety of produce has not been investigated. We hypothesized that fruits that are wet or water-congested will be more susceptible to contamination with enteric pathogens during harvest or immediately post-harvest. This susceptibility could be direct or indirect. Water intrusion into fruit through freshly exposed stem scars can accompany the harvest of fruit from wet plants such as during or immediately after rainfall, during heavy fogs or prior to the drying of dew or guttation. Wounds in the periderm associated with such harvests are also likely penetration points. At these times, free water can flood intercellular spaces within the fruit. Water congestion in plant tissues has previously been associated with the growth of incompatible bacteria that do not normally multiply in a particular plant, as well as with surface penetration by bacterial suspensions (through surface openings that connect congestive water with surface water). Therefore, water congested or wet fruit may make the product more susceptible to contamination from wiping cloths or from rubber gloves (if sources of the pathogen are present on cloths or gloves). Severe water congestion can lead to surface cracking, which destroys innate defenses of the fruit, and allows colonization of internal fruit

tissues in the field or at harvest. Whether water congestion per se would promote multiplication of *Salmonella* in tomatoes is unclear. Water congestion or fruit wetness make tomatoes or peppers vulnerable to plant pathogens, at least in part, because persistent water congestion appears to block certain types of host resistance such as programmed cell death. It is now clearly established that the presence of decay induced by plant pathogens promotes contamination of leafy greens, tomatoes, other fruits and vegetables with human enteric pathogens. Therefore, water congestion or fruit wetness can also indirectly reduce microbiological safety of the product. Establishing how these factors affect microbiological safety of tomatoes and peppers is the goal of this proposal. With this research we focused on testing how water status of the fruit affects susceptibility of tomatoes and peppers to post-harvest contamination with *Salmonella* in the presence or absence of plant pathogens, and whether *Salmonella* is capable of building up to levels capable of causing disease in humans under these conditions.

Research Methods and Results

Tomatoes of three cultivars (Florida 47, Solar Fire and Bonny Best) and one cultivar of bell pepper (cv. Aristotle) were grown in the research field at the UF-IFAS research plots in Citra (Central Florida) and in Live Oak (North Florida). Irrigation treatments were imposed within 2 weeks prior to harvest and consisted of three levels of maintained soil moisture, such that at the time of harvest the plants were subjected to insufficient water, optimal water, or will be overwatered. They were irrigated with well water by drip irrigation during daylight hours. Irrigation levels were maintained by monitoring soil moisture with a tensiometer or TDR. Approximate soil moisture tension values were -4 (over-irrigation), -10 (optimum), and -15/25 (insufficient) centibars on a tensiometer. The field experiment were a split-plot in randomized complete-block design with 4 blocks. Irrigation treatment were the main-plot and cultivar the sub-plot.

Inoculation with Salmonella. *Salmonella enterica* sv Typhimurium 14028 and a cocktail of *Salmonella* isolates that have been associated with produce outbreaks (svs. Javiana, Montevideo, Newport and Braenderup) were inoculated onto tomato surfaces by spotting 10 μl of the bacterial suspension (containing 100-1000 cells) onto a damp cotton cloth, and then rubbed on surfaces of tomato fruits for 30 seconds or by spotting the inoculum onto shallow (1 mm) wounds on tomato surfaces. For the assays, *Salmonella* will be recovered from surfaces and from internal tissues at the end of the week-long incubation period. They were stomached in saline (PBS, pH 7). In all cases, aliquots containing recovered bacteria were dilution-plated on a selective XLD medium.

Experiments on water congestion. Pericarp sections were floated on water to determine if water was absorbed and how duration of contact was correlated with an increase in weight. By 15 minutes, sections increased in weight by 6 to 9.6%. In addition to serving as a control for the irrigation studies, this set-up is directly relevant to the industry as it resembles the conditions under which sliced tomatoes are shipped to the restaurants.

Outcomes and Accomplishments

Water congestion. Water containing 0.1% Tween 80 was more likely to enter tissues (compared with tap or deionized water). Half-strength phosphate buffered saline was less likely to be absorbed as compared with deionized or tap-water suggesting that water uptake was caused in part by differences in water potential between the tissues and the water. Certain sections increased in weight by up to 20% if floated on water for 2 h. The rapid uptake of water by sections indicates the hazard of harvesting fruit while they are still wet with dew or rainfall or of allowing freshly harvested tomatoes to get wet with rainfall prior to arrival at a packinghouse.

Previous work with cell suspensions of fruit decay pathogens has consistently shown that water uptake correlates with inoculation (pathogen located in an infection court below the protective waxy cuticle). Surface treatments with chlorine or other sanitizers will not eliminate inocula that have migrated below the surface of wounded tissues. Prior water congestion affected proliferation of *Salmonella* in the pericarp sections depending on incubation temperature and fruit ripeness. Water congestion led to reduced proliferation when fruit were ripe but promoted proliferation in pink or green tomatoes. Incubation of pericarp sections at 35 versus 22^{o}C consistently enhanced proliferation of Salmonella by ca. 2.5-fold in 24 h and more than 10-fold within 48 h. Populations ranged from Log 6.7 cfu/wd after 24 h at 22C to Log 8.80 cfu/wd after 48 h at 35C. Prior water congestion enhanced the susceptibility of green or pericarp sections to *Geotrichum candidum*, but had no effect on bacterial soft rot. Including Silwet 77 (0.025% w/v) in the inoculum did not promote proliferation of *Salmonella* in tomato fruit and did not enhance water uptake (when used at this concentration, Silwet promotes inoculation of tomato leaves with various foliar bacterial pathogens). Significantly greater proliferation was observed in tests in which inocula were suspended in phosphate buffered saline (PBS) as compared with 0.1% peptone. In a second test, this was not confirmed.

The effect of irrigation regimes on susceptibility of tomato fruits to post-harvest *Salmonella* proliferation. One of main purposes of the project was to determine tomato susceptibility to *Salmonella* as affected by cultivar selection and irrigation regimes. As shown in Fig.1, irrigation regime did not affect susceptibility of green (immature) tomatoes to post-harvest contamination with *Salmonella.* The results are more nuanced in mature (red) tomatoes, and appear to be both the cultivar- and season-related. In mature tomatoes of cv. FL-47, significant differences in proliferation of *Salmonella* observed according to the irrigation regime (Fig.1, dotted box).

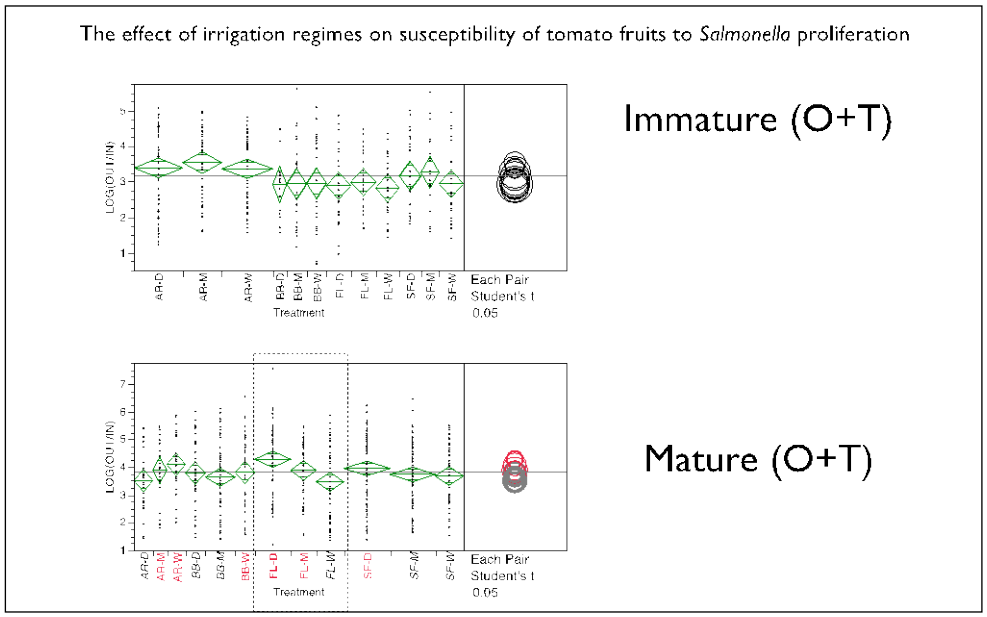

Fig. 1 Proliferation of *Salmonella* in immature and mature pepper and tomatoes as a function of irrigation regimes. AR= bell peppers var. Aristotle. SF= tomato var. Solar Fire; BB=Tomato var. Bonny Best. FL= tomato var. Florida 47. Irrigation regimes: D, low; M, recommended, W, high. Green diamonds that do not overlap are significantly different. Venn diagrams on the right of each figure indicate data overlaps.

However, there appear to be impacts of the weather-related effects or other field conditions. As shown in Fig. 2, FL-47 tomatoes grown under the recommended irrigation regime were the least conducive to the proliferation of *Salmonella*, except for the season B where above-average rainfall occurred during the harvest season.

Max Teplitski, University of Florida

Irrigation regime, fruit water congestion and produce safety: parameter optimization to reduce susceptibility of tomatoes and peppers to post-harvest contamination, pathogen transfer and proliferation of Salmonella

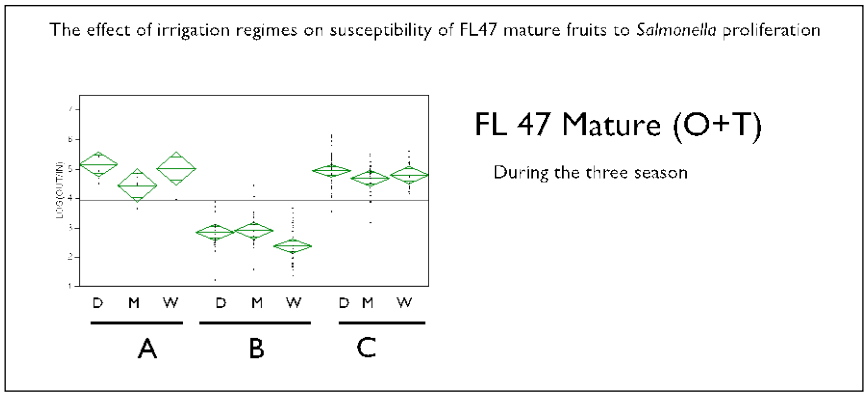

Fig. 2 Proliferation of *Salmonella* in mature Florida 47 as a function of irrigation regimes. Irrigation regimes: D, low; M, recommended, W, high. Season A: June 2011, B: June 2012; C: October 2012. Green diamonds that do not overlap are significantly different.

Proliferation of *Salmonella* in tomatoes as a function of fruit maturity. Based on the data collected during the three seasons, across all treatments, the maturity stage of the tomato had the biggest effect on the susceptibility of the fruit to proliferation of *Salmonella*. *Salmonella* proliferation is strongly determined by fruit ripeness. Stage 6 is significantly most susceptible to *Salmonella* proliferation if compared with other stages for both the cultivars and strains (Fig. 3). The trend was confirmed during each season, as shown in Figure 4.

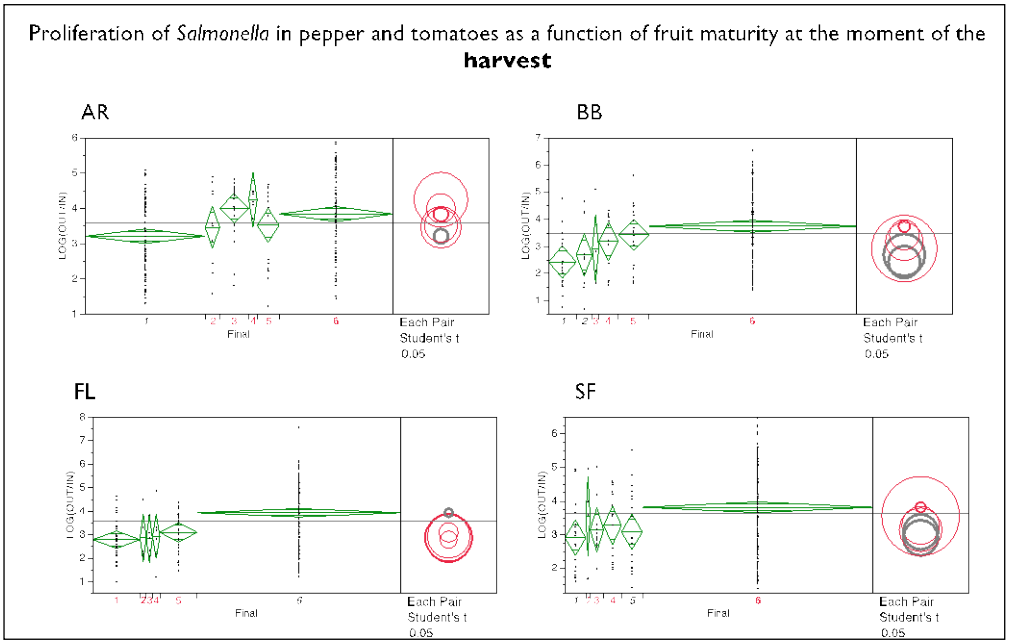

Fig. 3. Proliferation of *Salmonella* in tomatoes and pepper as a function of fruit maturity. Maturity stages were recorded at the moment of the harvest. AR= bell peppers var. Aristotle. SF= tomato var. Solar Fire; BB=Tomato var. Bonny Best. FL= tomato var. Florida 47. Tomatoes (and pepper) at maturity stages USDA 1 (green), 2 (breaker), 3 (turning), 4 (pink) and 5 (light red) were significantly less conducive to *Salmonella* proliferation compared to tomato at stage 6 (red). Green diamonds that do not overlap are significantly different. Venn diagrams on the right of each figure indicate data overlaps.

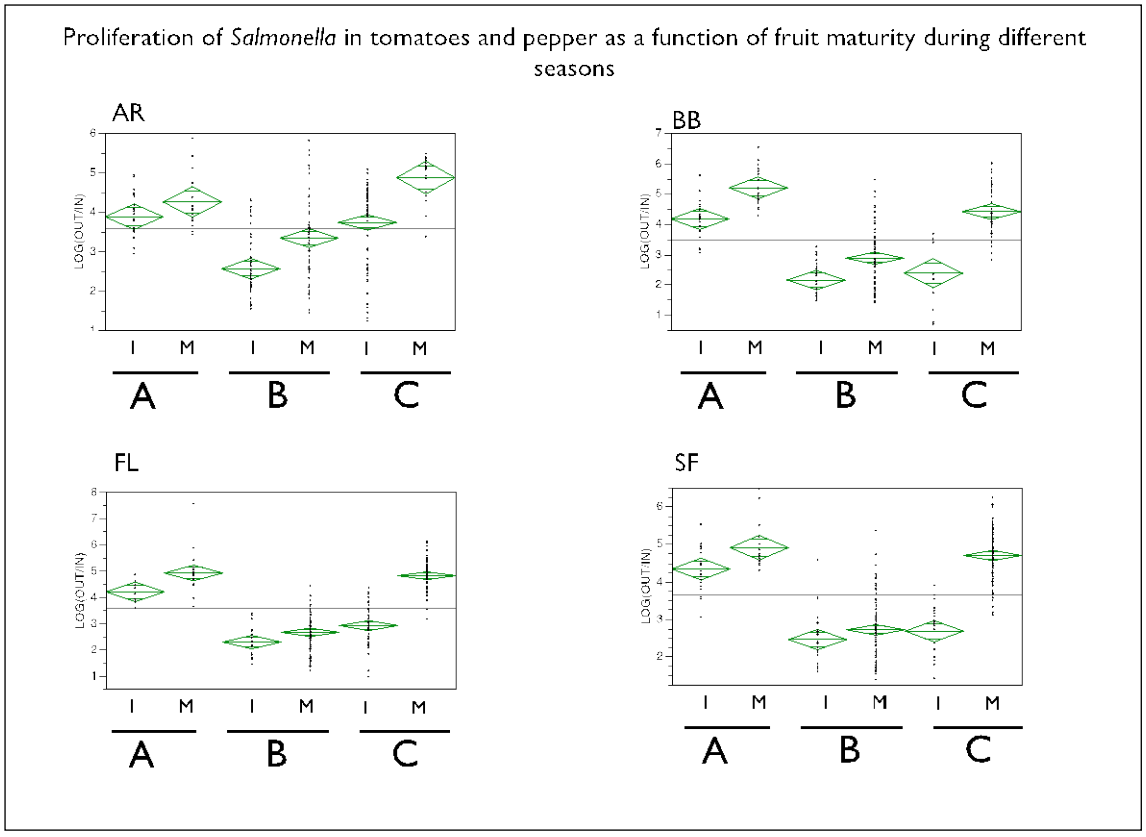

Fig. 4. Proliferation of *Salmonella* in tomatoes and pepper as a function of fruit maturity for each season. Maturity stages were registered at the moment of the infection AR= bell peppers var. Aristotle. SF= tomato var. Solar Fire. BB=tomato var. Bonny Best. FL= tomato var. Florida 47. Data from the type strain of *Salmonella* 14028 (T) or the "outbreak strains" (O) were summed for the analysis. I= immature (stage 1-5). M= mature (stage 6). Green diamonds that do not overlap are significantly different. Season A: June 2011, B: June 2012; C: October 2012.

The effect of the *Salmonella* strains on susceptibility of bell pepper and different tomato cultivars and maturity stages. Proliferation of *Salmonella* of type strain 14028 and an outbreak cocktail was compared in peppers var. Aristotle, and tomatoes Bonnie Best, Solar Fire and FL-47 at mature and immature stage. When all other factors such as irrigation regimes were held equal, our analysis did not show significant differences in immature and mature fruits and among the cultivar analyzed (Fig. 5). According to these results, the *Salmonella* genotype does not have a dramatic effect on proliferation of the pathogen inside crops, once the contamination took place under the field conditions and using the protocols that were used in this study.

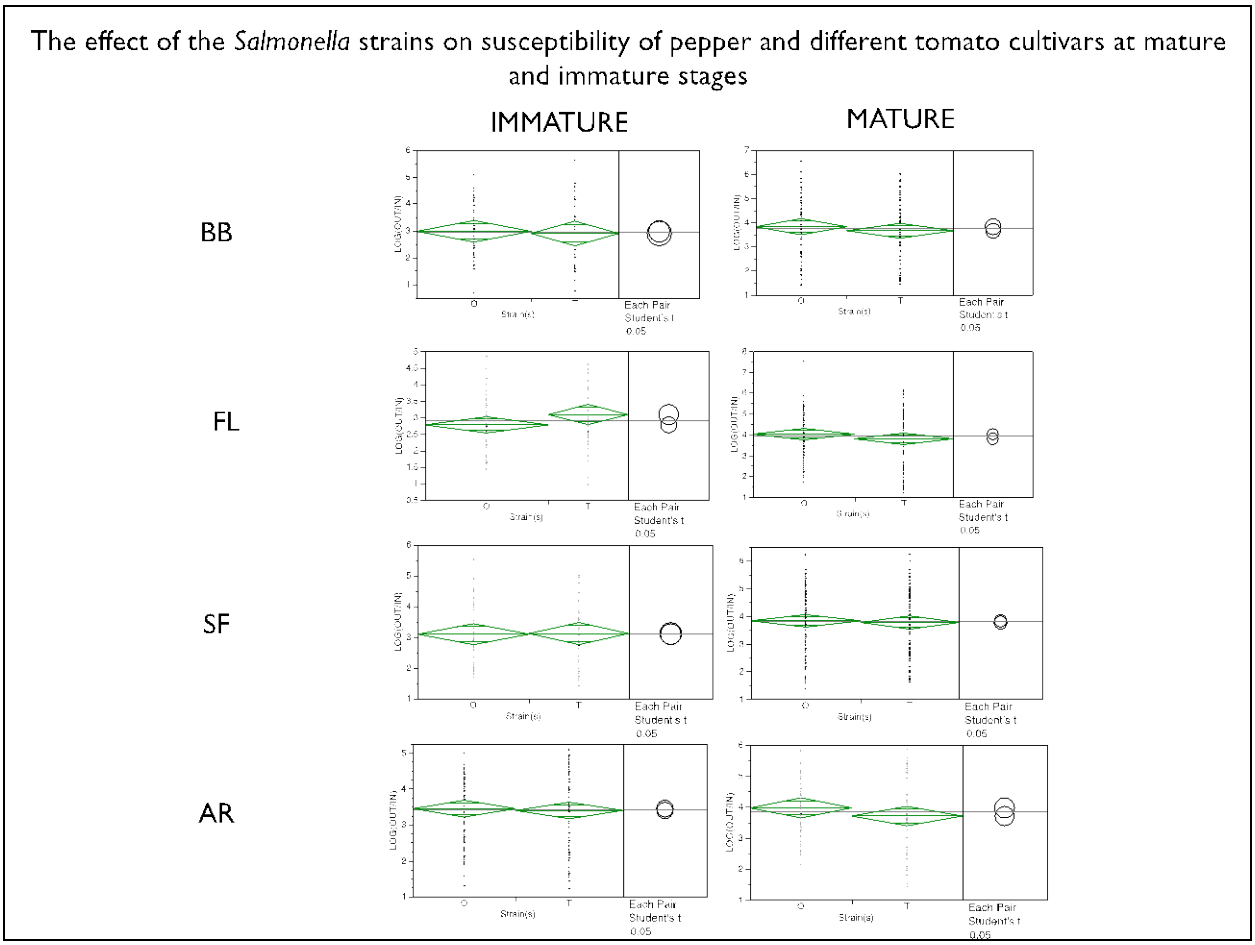

Fig. 5 Proliferation of *Salmonella* (Type strain 14028 or a cocktail of Outbreak strains) in immature and mature pepper and tomatoes as a function of tomato cultivar and maturity stages. AR= bell peppers var. Aristotle. SF= tomato var. Solar Fire; BB=Tomato var. Bonny Best. FL= tomato var. Florida 47. Proliferation of the type strain of *Salmonella* 14028 (T) and the "outbreak strains" (O). Green diamonds that do not overlap are significantly different. Venn diagrams on the right of each figure indicate data overlaps.

The effect of the cultivar on susceptibility of tomato fruits to *Salmonella* proliferation.

Proliferation of *Salmonella* was compared in Aristotle pepper, and tomatoes cv. Bonnie Best, Solar Fire, and FL-47 at immature (1-5 stages) and mature stage (6). When the proliferation of *Salmonella* was compared between the cultivar at the immature stages (up to USDA 5), the bell peppers cv. Aristotle was significantly more susceptible than the tomatoes cultivars (~0.4 log of difference, Fig. 6). When the three seasons were compared, peppers were more susceptible in season B and C (Fig. 6, bottom panel). No significant differences were seen among tomato cultivars, averaged across treatments. When the proliferation of *Salmonella* was compared among all tested plant genotypes at the mature stage did not yield results that were significantly different (Fig. 7) under the field conditions.

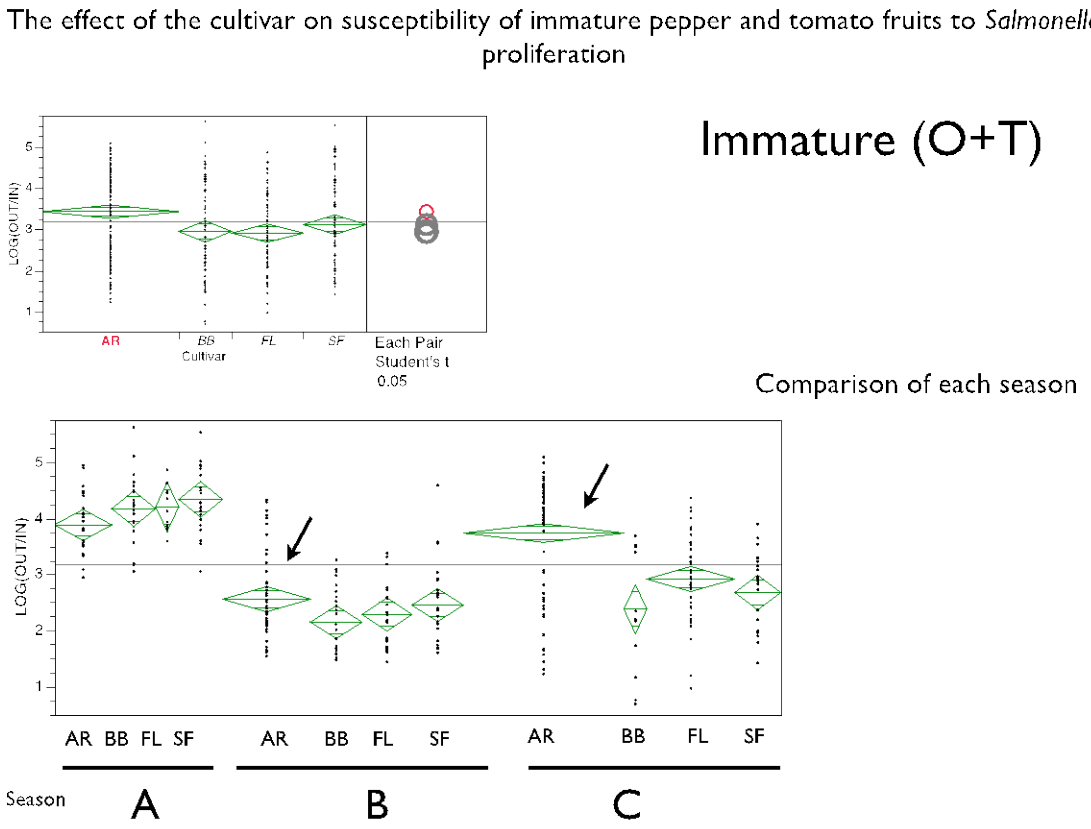

Fig. 6. Proliferation of *Salmonella* (T+O strains) in immature tomatoes as a function of different cultivars. Top panel: Proliferation of *Salmonella* in immature tomatoes as a function different cultivars. AR= bell peppers var. Aristotle. SF= tomato var. Solar Fire; BB=Tomato var. Bonny Best. FL= tomato var. Florida 47. Bottom panel: Comparison of proliferation of *Salmonella* in immature tomatoes as a function of different cultivars during the three seasons. Arrows indicate the highest proliferation in immature peppers when compared with tomatoes. Green diamonds that do not overlap are significantly different. Venn diagrams on the right of each figure indicate data overlaps. Season A: June 2011, B: June 2012; C: October 2012.

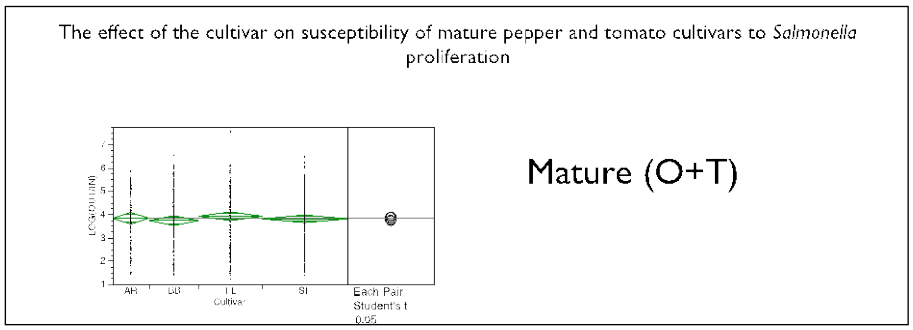

Fig. 7. Proliferation of *Salmonella* (T+O strains) in mature tomatoes as a function of different cultivars. AR= bell peppers var. Aristotle. SF= tomato var. Solar Fire; BB=Tomato var. Bonny Best. FL= tomato var. Florida 47. Green diamonds that do not overlap are significantly different. Venn diagrams on the right of each figure indicate data overlaps.

The effect of fruit and plant defects on the susceptibility of tomato fruits to *Salmonella* proliferation.

During the third season we analyzed the effect of fruit damage and plant defects on the susceptibility of tomato fruits to *Salmonella* proliferation. Note, that damaged fruits were not used in this assay. Rather, we use the rating as an indirect assessment of plant health. The analysis was performed observing the tomatoes and assigning a rating to the plats/tomatoes using the Horsfall-Barratt system. Fruit defects were mostly radial cracking some of which was severe. Some severe roughness was also observed primarily among fruit of BB. Fruit cracking was based on observations of harvested fruit in the field and of fruit that had been sized and sorted. Foliage cover was an attempt to estimate amount of green foliage left. Necrotic foliage was a combination of tomato yellow leaf curl virus and bacterial spot. Most of the necrosis can be attributed to the latter, whereas moderate to severe stunting accompanied the virus. No evidence of significant correlation among fruit and plant defects on the susceptibility of tomato fruits to *Salmonella* proliferation were reported (Fig. 8). Analyses were also done independently on the cultivars/irrigation regimes without observing any significant differences.

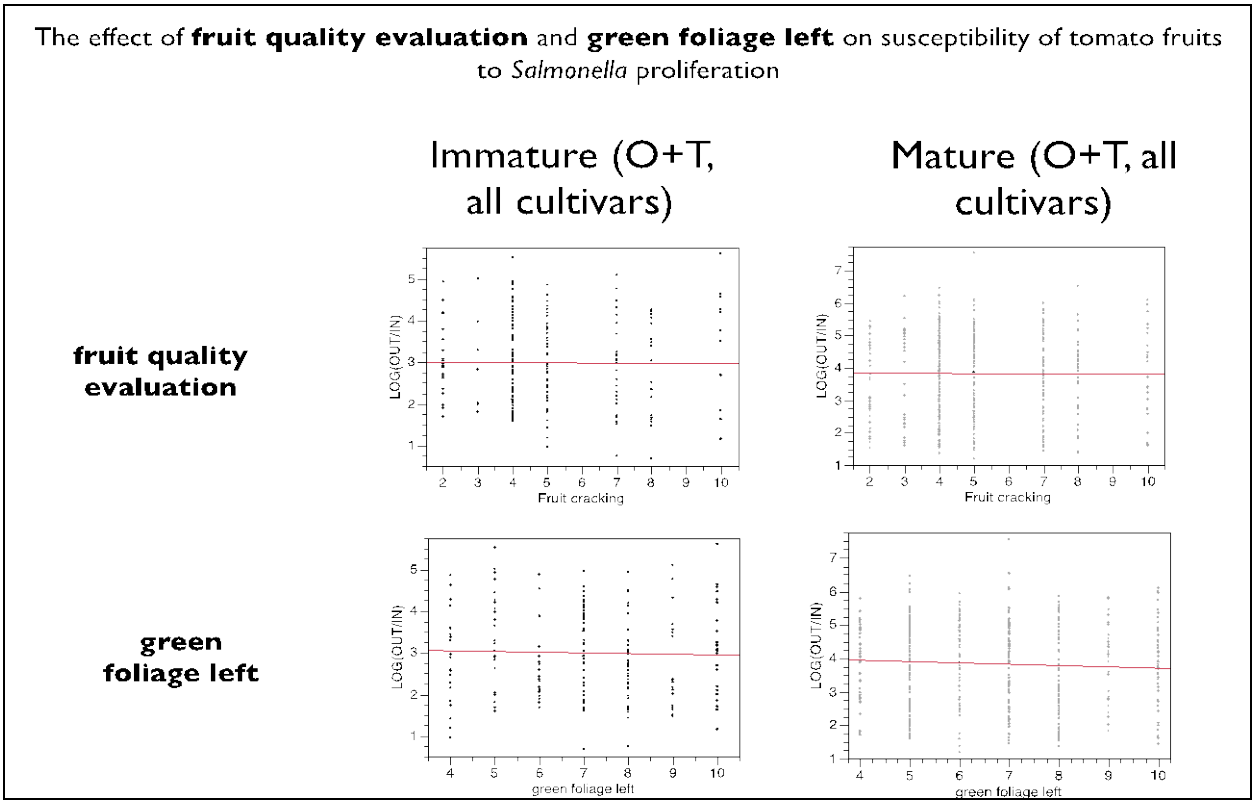

Fig. 8. Fruit and plant defects on susceptibility of tomato fruits to *Salmonella* proliferation. *Salmonella* strains and cultivar were kept equal. The numerical values reported on the X axes reflect the percentage of the area showing disease symptoms (low score = low symptoms/damage).

Persistence of *Salmonella* on the tomato surface upon rubbing with cotton cloth. It has been hypothesized that differences in the irrigation regime will affect the ability of the introduced pathogen to proliferate on fruit surfaces.

Three days of incubation reduced significantly the number of cell recovered. This reduction is significant for all the fertilization/cultivar tested when immature and mature tomatoes are kept equal (Fig. 9). If the persistence is calculated at different maturity stages, the persistence is equally reduced in immature/mature but not significant for all the treatment/cultivars. No significant differences resulted when different cultivars and irrigation regimes were analyzed.

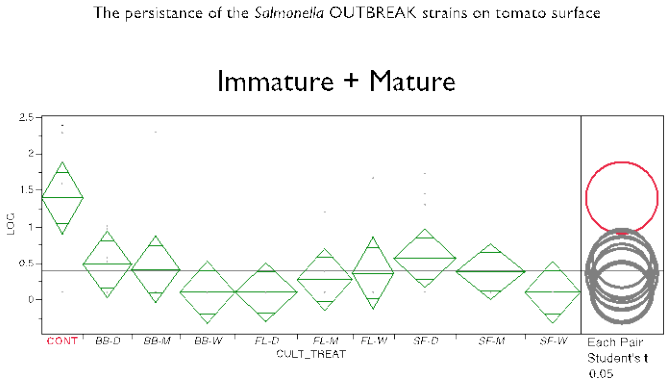

Figure 9. Persistence of *Salmonella* on the surface of immature and mature tomatoes as a function of irrigation regimes and cultivars. AR= bell peppers var. Aristotle. SF= tomato var. Solar Fire; BB=Tomato var. Bonny Best. FL= tomato var. Florida 47. Irrigation regimes: D, low; M, recommended, W, high. Green diamonds that do not overlap are significantly different. Venn diagrams on the right of each figure indicate data overlaps.

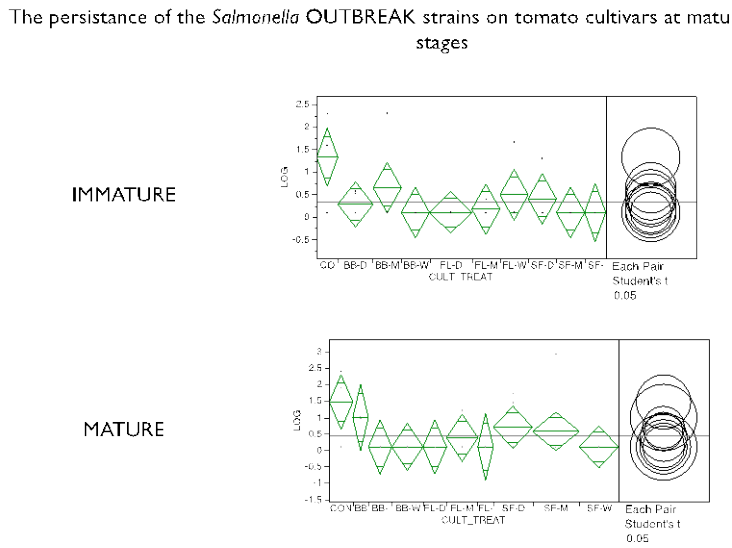

Figure 10. Proliferation of *Salmonella* on the surface of immature and mature tomatoes as a function of irrigation regimes and cultivars. SF= tomato var. Solar Fire; BB=Tomato var. Bonny Best. FL= tomato var. Florida 47. Irrigation regimes: D, low; M, recommended, W, high. Green diamonds that do not overlap are significantly different. Venn diagrams on the right of each figure indicate data overlaps.

We have also tested the mechanisms by which *Salmonella* is interacting with plant pathogens in damaged tomatoes. Our results demonstrate that within soft-rots *Salmonella* reaches population densities 10-100 fold higher than within intact plants. The hypothesis that *Salmonella* exchanges AI-2 signals with *Pectobacterium carotovorum* to increase its competitive fitness was tested using mutants involved in AI-2 production (*luxS*) or perception (*lsrACDBF* or *lsrG*). Co-infections of wild-type *Salmonella* and its AI-2 mutants (at ~3-10^4) were established in green or red tomatoes (cv. FL 47 or Campari, for 3 or 5 days) as well as tomatoes co-infected with *Pectobacterium* (at 10^9) or its *luxS* mutant. There were no significant differences in the competitive fitness of *Salmonella*, indicating AI-2 signaling is not a major input in the interactions between the organisms under the tested conditions. A *Salmonella lsrG::tnpR-lacZ* RIVET reporter, constructed to monitor AI-2 related gene expression, responded strongly to the *luxS*

deletion but only weakly to external sources of AI-2. Growth in soft-rots generally decreased RIVET resolution, however, the effect was not correlated to *Pectobacterium's luxS* genotype. The results of this study show that AI-2 signaling offers no significant benefit to *Salmonella* in this model of colonization of tomatoes or soft-rots.

Summary of Findings and Recommendations

Various aspects of Salmonella interaction with tomato fruit can be modeled by use of sections of pericarp. Pericarp sections are easy to handle, require little space, are easily stored under various environments and can be extracted for bacteria with 2 to 4 ml of sterile phosphate buffered saline. Growth of contaminating decay pathogens such as soft rot bacteria, soft-rotting fungi or fruit endophytes or epiphytes have not affected proliferation of Salmonella on fruit tissues. Inoculated sections have been held up to 72 h at 22^{o}C. Salmonella populations on sections increased from ca. Log 3.0 after inoculation to Log. 7.5 by 24 h and up to Log 8.8 by 48 h. Pericarp sections can be water congested by floating them on water for 30 to 60 min. Movement of water would be through the cut edges as well as the bottom. The process did not seem to promote fruit decay or the growth of contaminating bacteria. Water moves into fruit rapidly, which emphasizes the hazards of harvesting fruit when the plants are wet or of allowing freshly harvested fruit to be exposed to uncontrolled water (such as rainfall, or any water that does not contain a sanitizer). Water movement into fruit appears to be reduced when salts are present suggesting that tissue water potential is a factor. Tomato fruit tissues respond differently to free water when pink or green as opposed to red. Salmonella proliferation is promoted (statistical increase in populations recovered) by water congestion in green or pink tomatoes but not red tomatoes. High storage temperatures (35^{o}C) consistently promote proliferation.

Tomato maturity appears to have the most significant effect on the proliferation of *Salmonella* in tomatoes once contamination takes place. Differences in irrigation regime (imposed within 2 weeks prior to harvest) did not significantly impact the ability of *Salmonella* to proliferate in the fruit. Because only three tomato varieties were tested in this field study, it is difficult to definitively establish and broadly conclude whether tomato genotype had a role in susceptibility of the crop to *Salmonella*. Consistent differences were observed in the proliferation of *Salmonella* in peppers vs tomatoes.

APPENDICES

Publications and Presentations (required)

1. Brandl, M., Cox, C.E., Teplitski, M. 2013. *Salmonella* interactions with plants and their associated microbiota. *Phytopathology.* Accepted
2. Cox, C.E., McClelland, M., Teplitski, M. 2013. Consequences of disrupting *Salmonella* AI-2 signaling on interactions within soft rots. *Phytopathology* dx.doi.org/10.1094/PHYTO-09-12-0237-FI
3. Bartz, J., Mahovic, M., Spiceland, D., Teplitski, M. 2012. Detached leaf assay adapted to tomato pericarp sections for modeling contamination of tomato fruit by *Salmonella* Typhimurium. *Phytopathology* **102** (7): S4.9
4. Teplitski, M., Noel, J.T., McClelland, M., Creary, E., Alagely, A. 2011. High throughput screens reveal *Salmonella* behaviors required for persistence in tomatoes. *Phytopathology* **101** (6): S176
5. Zaragoza, W., Teplitski, M. 2011. The effect of phase variation on the interactions of *Salmonella enterica* sv. Typhimurium with tomatoes. *Phytopathology* **101** (6): S200
6. Noel, J.T., Teplitski, M. 2011. Does pectolytic activity of phytopathogens enhance *Salmonella* proliferation in tomato fruits? *Phytopathology* **101** (6): S212-S213

Presentations:

1. Teplitski, M. Irrigation regime, fruit water congestion and produce safety: parameter optimization to reduce susceptibility of tomatoes and peppers to post-harvest contamination, pathogen transfer and proliferation of *Salmonella.* Produce Research Symposium, Center for Produce Safety, University of California-Davis. June 27, 2012
2. George, A. , Noel, J., Teplitski, M. 2012. The role of *P. carotovorum* in the increased proliferation of *S.* Typhimurium in tomatoes (Poster Presentation). 2012 Annual Education Conference, Florida Association for Food Protection, Wyndham Lake Buena Vista, Orlando, FL. May 9-11, 2012
3. Gause, E., Noel, J., Marvasi, M., George, A., Teplitski, M. 2012. Proliferation and performance of *Salmonella* in various cultivars of tomato (Poster Presentation). 2012 Annual Education Conference, Florida Association for Food Protection, Wyndham Lake Buena Vista, Orlando, FL. May 9-11, 2012
4. George, A., J.Noel, E. Gause, M. Teplitski. The role of *Pectobacterium carotovorum* in increased proliferation of *Salmonella enterica* Typhimurium in tomatoes. (Oral Presentation) 97th Annual Meeting of Southeastern Branch of American Society for Microbiology, Gainesville, FL. October 20-22, 2011.
5. Teplitski, M. Toward a safer harvest: functional genomics analysis of *Salmonella*-tomato interactions. Plant Pathology Department, University of Florida. December 6, 2011.
6. Teplitski, M. Toward a safer harvest: functional genomics analysis of *Salmonella*-tomato interactions. Co-sponsored by Plant Pathology Department and BTI, Cornell University. November 16, 2011. Ithaca, NY.
7. Teplitski, M. (Oral Presentation) Does pectolytic activity of phytopathogens enhance *Salmonella* proliferation in tomato fruits? Joint Meeting American Phytopathological Society – International Society of Plant Protection, August 6-10, 2011. Honolulu, HI
8. Teplitski, M. (Oral Presentation) Toward a safer harvest: using functional genomics to understand *Salmonella*-tomato interactions and promoter safer produce. Global Food Security and Plant Biosecurity Symposium. November 8-9, 2011. Baton Rouge, LA.

9. Teplitski, M. (Oral Presentation) Reducing tomato contamination with *Salmonella* through cultivar selection and maturity at harvest. Produce Research Symposium. June 28, 2011. Orlando, FL
10. Teplitski, M. *Salmonella*'s plant-associated life styles: current uncertainties. Training session at Advanced Topics in Microbial Safety of Fresh Produce (Organizers: Harris, L., Suslow, T., Schneider, K.) UC-Davis Post Harvest Technology and USDA Specialty Crops Projects. April 27-29, 2011. UF-IFAS Gulf Coast Research and Education Center, Balm, FL.
11. Teplitski, M. (Oral Presentation) Cultivar selection, maturity at harvest and susceptibility of tomatoes to contamination with *Salmonella*. Produce Marketing Association Fresh Summit 2010 (trade show). October 15-18, 2010. Orlando, FL

Budget Summary (required)

Tables and Figures (optional)

Suggestions to CPS (optional)