

Temperature Declines During Storms and Irrigation May Contribute to Fire Blight Infection of Pear Fruit

David A. Rosenberger and Keri L. VanCamp, Department of Plant Pathology, New York State (Geneva) Agricultural Experiment Station, Cornell University's Hudson Valley Laboratory, P.O. Box 727, Highland, NY 12528

Corresponding author: David A. Rosenberger. dar22@cornell.edu

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Abstract

During summer of 2002, fire blight caused by *Erwinia amylovora* appeared in immature pears (*Pyrus communis*) in five Ulster County pear orchards in southeastern New York State. Foliar symptoms of fire blight were absent or infrequent in many trees that had infected fruit, suggesting that fruit infections occurred after shoots had stopped growing and were no longer susceptible to infection. In one orchard where overhead irrigation was initiated on 23 July when air temperatures were 96°F, incidence of fruit infection in September ranged from 10 to 76% with a mean of 36% of all fruit showing fire blight symptoms. Laboratory experiments showed that non-wounded fruit preheated to 95°F and then submerged in inoculum suspensions at 70°F or 40°F developed fire blight infections whereas similar fruit preheated at 70°F and immersed in 70°F-inoculum did not develop infections. Overhead irrigation initiated during the heat of the day can disperse inoculum at the same time that rapid cooling from irrigation water may cause *E. amylovora* to be drawn into immature pear fruit. The same combination of water-disseminated inoculum and rapid cooling can occur during summer thunderstorms, and storm events may explain the unusual incidence of fire blight on immature pears that was observed in 2002.

Introduction

Fire blight caused by *Erwinia amylovora* (Burrill) Winslow et al. is the most important bacterial disease of pome fruits in United States and many other parts of the world (2). The infection process in blossoms has been extensively studied (9). Factors contributing to blossom infections have been defined and used to develop predictive models that assist farmers in proper timing of antibiotic sprays that can be used to protect blossoms from infection (7,8). After bloom, injuries caused by hail can provide entry sites for secondary spread of fire blight. However, factors that contribute to secondary spread of fire blight in the absence of hail have been more difficult to define. Various researchers have suggested that *E. amylovora* infects growing terminal shoots and immature fruit via small injuries caused by wind-whipping during rain storms (2,5,9). However, spread of fire blight during summer remains largely unpredictable.

An unusual pattern of secondary fire blight infections in pear (*Pyrus communis*L.) fruit was observed in five orchards in the Hudson Valley of New York during July and August of 2002. Research was conducted to determine what factors might have contributed to the severe fruit infections observed in these orchards.

Field Observations

On July 19, a farmer near Milton, NY, reported fire blight on immature Bosc pear fruit (Orchard 1). He had seen a few "decayed" fruit in trees several days earlier, but he became concerned when the numbers of fruit affected began to escalate. Fruit collected from Orchard 1 on July 24 showed external ooze droplets typical of fire blight infections in fruit. Samples were sent to William Turechek, Department of Plant Pathology at the Geneva (New York) Agricultural

Experiment Station, who confirmed the presence of *E. amylovora* by isolating the bacteria from infected fruit (*personal communication*, W. W. Turechek).

Several adjacent trees in Orchard 1 showed extensive fire blight symptoms on shoots on 24 July, but most trees had either no shoot blight or only a few strikes in vigorous shoots in the tops of the trees. Pear fruit with fire blight symptoms were scattered throughout the tree canopy in trees within several hundred feet of the severely affected trees. In most cases none of the subtending spur leaves showed any evidence of fire blight (Fig. 1). By July 24, most of the terminal shoots had ceased growing, and shoot blight infections in the tops of the trees were sometimes limited to the top one-third of the current season's growth as typically occurs when vegetative growth ceases and shoots become resistant to further infection and invasion by *E. amylovora*. The incidence of fruit infection in this orchard could not be determined because the grower had picked and destroyed infected fruit as they appeared to reduce the potential for secondary spread. On July 24, five to 10 infected fruit per tree were still evident in the trees closest to the severely infected trees that presumably supplied inoculum.



Fig. 1A and 1B. Fire blight symptoms on immature Bosc pear fruit showing infected fruit on spurs that have no symptoms of fire blight.

Over the next two months, similar fire blight symptoms on fruit were observed in three additional Bosc pear orchards near Milton, New York, and in one DeVoe pear orchard near Ulster Park, New York. On August 12, a farmer reported seeing infected pear fruit in a Bosc pear orchard (Orchard 2) where a single tree had one limb killed earlier in the summer due to enlargement of an over-wintering canker, but none of the other trees had shown any infected blossoms or shoots during June. The farmer had assumed that no further spread of fire blight would occur after mid-July because of the dry summer and the fact that most terminal shoots had stopped growing by mid-July. During a visit to Orchard 2 on 12 August, we noted that fruit blight infections were scattered throughout Bosc pear trees in the proximity of the tree that had canker blight earlier in the summer. A few infected fruit were also observed on the Bartlett pear pollinator trees in the same orchard.

Similar blighting of immature fruit, with no symptoms on the subtending spur leaves, were later observed in Orchards 3 and 4. Trees in Orchard 4 had more vigorous vegetative growth than trees in the other orchards, and many trees in Orchard 4 were severely affected by shoot blight. The presence of infected fruit on healthy spurs would have gone unnoticed in Orchard 4 if we had not specifically looked for these symptoms after seeing them in other orchards.

In Orchard 5, blight was observed on immature pear fruit on a single DeVoe pear tree located in a Bosc pear orchard adjacent to an apple orchard that had scattered blossom infections during spring of 2002. The DeVoe pear tree showed no symptoms of fire blight on foliage at the time fruit were harvested, but the farmer reported that a high percentage of the DeVoe fruit had fire blight symptoms at harvest and several infected fruit remained in the trees at the time of our visit. Adjacent Bosc trees in Orchard 5 did not develop the fruit blight symptoms that were observed on the DeVoe tree.

Irrigation as a Factor in Fruit Infection

The owner of Orchard 2 reported that on 23 July he had set up an overhead irrigation “gun” on a portable tower located near the tree canker blight. The irrigation gun released approximately 225 gal/min and distributed the water in a circular pattern with a radius of 120 ft. Water was pumped through the gun for about 4 hr providing the equivalent of about 2 inches of rainfall. The irrigation was started about 1:00 p.m. on 23 July at a time when air temperature was 96°F. Because the irrigation gun was mounted on a tower, the water from the gun did not contact trees directly during its upward trajectory. However, the flapper on the gun that causes the gun to rotate may have diverted a discontinuous spray of water directly over the inoculum source in this block. On August 12, we noted numerous infected fruit per tree in the irrigated section of the orchard whereas only one or two infected fruit per tree were evident in nearby non-irrigated sections of the same block. There was no reason to suspect that *E. amylovora* originated in the pond water used to irrigate Orchard 2 because the same pond was used to irrigate other pear blocks on the same farm, and fire blight developed only in Orchard 2 where there was a known source of fire blight inoculum.

In Orchard 2, the incidence of fruit blight for 15 trees in the proximity of the source tree was determined on 10 September. Diseased fruit both on the ground and on the tree were counted, and the healthy fruit remaining on the trees were also counted. Trees evaluated for the incidence of fruit blight were selected arbitrarily with the objective of finding representative trees throughout the orchard while avoiding trees where dense ground cover, including poison ivy (*Rhus radicans* L.), would interfere with counting diseased fruit on the orchard floor.

No irrigation was used in any of the other four orchards where infected fruit were noted on healthy spurs. Weather records from the Hudson Valley Laboratory in Highland, eight miles north of Orchard 2, were evaluated to determine if summer thunderstorms might produce rapid temperature declines similar to those expected when irrigation water is applied on a hot day.

Laboratory Experiments

Because previous reports had shown that rapid cooling in water flumes contributed to postharvest decays of tomatoes (1), we conducted an experiment to determine if rapid cooling of pear fruit by irrigation water or rain during thunderstorms could have contributed to fruit infection. Immature Bosc pear fruit were harvested from an orchard with no fire blight on 14 Aug and were used for inoculation experiments in the laboratory. Diseased fruit were harvested from two trees close to the source tree in Orchard 2 and were used to prepare inoculum for the lab tests.

Inoculum was prepared by placing approximately 150 diseased fruit in a 5-gal pail and covering them with 1.8 gal of distilled water. The pears were swirled gently in the water, allowed to soak for 20 min, then removed from the liquid. This bacterial stock suspension appeared cloudy in transmitted light. Final inoculum suspensions were made by mixing 20 fl oz of the stock solution with 32 fl oz of distilled water in large beakers. Concentrations of *E. amylovora* in the final inoculum suspensions were determined by dilution plating.

The harvested test fruit were randomly assigned to 12 groups of 10 fruit each. The fruit in six groups were wounded on a single hemisphere using a large cork fitted with three 6d finishing nails spaced about 3/8th inch apart in a triangular pattern so as to produce wounds that were approximately 1/8th inch deep by 1/16th inch in diameter. Eight groups of 10 pears, half wounded and half non-wounded, were held at 95°F for 2 hr prior to inoculation and four groups were held at 70°F after which half of the groups from each temperature were immersed for 20 min in distilled water adjusted to either 70°F or 40°F and the other half were similarly immersed in temperature-adjusted inoculum suspensions. Only five fruit could be treated in a single beaker, so each group of 10 fruit was subdivided into two separate beakers for inoculation. Inoculated fruit were held at 100% relative humidity and ambient laboratory temperature (about 75°F) from the time of inoculation until observations were completed six days later. The treatment involving 95°F fruit and 40°F inoculum exceeded temperature extremes that might occur in nature, but that treatment was

included so as to detect any possibility that temperature differentials between fruit and inoculum might affect fruit susceptibility to infection. Wounded fruit were included in the experiment as a positive control for inoculum viability.

The experiment was repeated on 21 Aug using freshly-harvested test fruit from the same orchard and freshly-harvested diseased fruit to prepare inoculum.

Results of Field Observations

Total crop load on trees in Orchard 2 that were evaluated for the incidence of fruit infections varied from 21 to 368 fruit per tree with a mean of 149 fruit per tree. The incidence of fruit infections for the 15 trees ranged from 10 to 76% with a mean of 36.3% of total fruit infected. The trees with the highest incidence of fire blight in fruit were southeast of both the fire blight source tree and the location of the irrigation gun on 23 July (Fig. 2).

Rapid temperature drops associated with afternoon thunderstorms occurred four times between 9 July and 2 August of 2002 (Fig. 3).

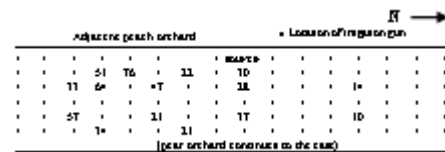


Fig. 2. Map of Orchard 2 showing the source tree for fire blight infections, the location of the irrigation gun on July 22, and the percentage of the total fruit load on 15 monitored trees that had fire blight infections by 10 September.

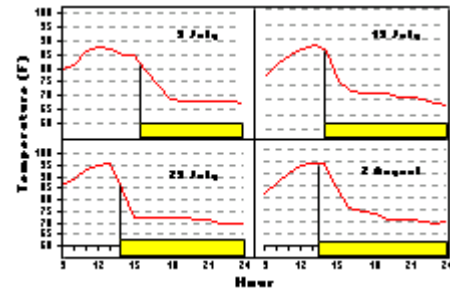


Fig. 3. Temperatures (red line) and wetting periods (yellow bar) as measured in Highland, New York, for four days during 2002 when rapid temperature declines may have contributed to infection of immature pear fruit by *E. amylovora*.

Results of Laboratory Trials

Water-soaked lesions appeared on inoculated fruit five days after inoculation (Fig 4). By day 6, symptoms appeared on a high proportion of wounded fruits for all fruit temperature and inoculum temperature combinations (Table 1). On non-wounded fruit, however, none of the 20 fruits (Trials 1 and 2 combined) developed fire blight when fruit held at 70°F were immersed in inoculum at 70°F. By comparison, the 95°/70°F fruit/inoculum temperature combination resulted in 70% of non-wounded fruit becoming infected and the 95°/40°F temperature combination resulted in 85% of non-wounded fruit becoming infected. On wounded fruit, the treatments had a similar effect on the incidence of infections appearing at non-wound locations on the fruit (Table 1), whereas temperature treatments had no effect on the proportions of wounds that became infected. No fire blight infections developed in any of the wounded or non-wounded control fruit that were immersed in water instead of being exposed to inoculum.



Fig. 4. Fire blight symptoms five days after immature fruit that had been preheated to 95°F were immersed in a 70°F-inoculum suspension of *Erwinia amylovora*.

Table 1. Fire blight infections observed on detached Bosc pear fruit 6 days after immature fruit were inoculated in the laboratory.

Inoculation temperature differentials	Non-wounded fruit		Wounded fruit		
	% fruit infected	Mean No. of infections per fruit	Infections at non-wound sites		% of wounds infected
			% fruit infected	No. of infections/fruit	
Trial #1: 14 Aug					
Fruit 70°F; inoc. 70°F ^y	0	0.0 a ^z	0	0.0 a	40.0
Fruit 95°F; inoc. 70°F	80	2.9 b	50	2.1 b	46.7
Fruit 95°F; inoc. 40°F	80	2.7 b	80	1.1 b	43.3
Trial #2: 21 Aug					
Fruit 70°F; inoc. 70°F ^y	0	0.0 a	0	0.0 a	73.3
Fruit 95°F; inoc. 70°F	60	1.8 b	40	0.9 a	60.0
Fruit 95°F; inoc. 40°F	90	1.3 b	40	0.6 a	66.7

^y The inoculum suspension for Trial 1 contained 2.6×10^6 cfu/ml and inoculum for Trial 2 contained 1.6×10^6 cfu/ml.

^z Means are derived from observations of 10 fruit. For each trial, means within columns followed by the same letter are not significantly different ($P \leq 0.05$) as determined by applying Fisher's Protected LSD test to log-transformed data.

Conclusions

The observations and experiments reported here provide evidence that unwounded immature pear fruit that are simultaneously exposed to water, *Erwinia amylovora*, and rapid temperature declines can develop fire blight symptoms. This is the first report indicating that rapid temperature declines associated with irrigation or thunderstorms may be involved in the epidemiology of fire blight during summer. Van der Zwet and Keil (9) noted that "Fruit blight is most common following a severe summer hailstorm." However, none of the orchards observed as part of this study received any hail during the thunderstorms that contributed to the rapid temperature declines.

Rapid temperature declines may contribute to fire blight infection by generating thermal contraction of air spaces within the fruit. Contraction of air within the fruit could create a "mini-vacuum" that would enhance penetration of bacteria through lenticels or microscopic cracks in the fruit surface. This

phenomenon has been explored with tomatoes where postharvest cooling in water flumes contributes to penetration of stem scars by several species of bacteria (1). However, the work reported here with fire blight in immature pear fruit is the first report to implicate rapid temperature declines as a factor in field epidemiology of bacterial diseases.

Discussion

Our lab experiments involved a minimum temperature shock of 25°F. Weather records showed that thunderstorms caused rapid declines of 16 to 24°F in air temperatures on at least four occasions during the summer of 2002. Although the recorded declines in air temperature were less than the temperature differential used in lab inoculations, the temperature shock to pear fruit in the field was greater than recordings of air temperature would suggest. Temperatures of apple fruit exposed to the sun can be 10 to 25°F above air temperatures (3,6), and water temperatures from irrigation or during thunderstorms can be lower than the recorded air temperatures. The temperature of the water used for irrigation on 23 July is not known. The water temperature in the farm pond used for irrigating was 75 F on 10 September, but it was probably somewhat colder on 23 July when the pears were irrigated. If one assumes that the temperature of the pond water was 72°F on 23 July and that internal fruit temperature for fruit exposed to the sun was 10°F greater than the 96°F recorded for air temperature on 23 July, then fruit in the field may have been experienced a 34°F drop in temperature (106°F to 72°F) between 2:00 p.m. and 4:00 p.m. on 23 July. Presumably there is some threshold combination of temperature decline and fruit wetting duration that is required for infection of immature pear fruit during summer. Additional research will be required to define those limits.

The crude inoculum used for our laboratory experiments may have contained organisms other than *E. amylovora*, but those same organisms would have been disseminated in the orchard as well. The fact that pear fruit exposed to inoculum in the absence of a temperature decline did not develop disease of any kind provides evidence that the inoculum did not contain other known pathogens.

Fruit susceptibility to infection may vary with cultivar and with maturity, and those differences could explain why DeVoe pears developed fire blight in Orchard 5 whereas adjacent Bosc pears in that orchard did not. The thunderstorm on 23 July delivered 0.55 inch of rain at our weather station in Highland, more than 2 inches of rain in Orchards 1-4 which were located roughly eight miles to the south and virtually no rain in Orchard 5, which was located seven miles to the north of Highland. Based on the grower's account of when blight symptoms appeared, it seems likely that the DeVoe pears became infected during the rain on 2 August or perhaps even later in August. Infections in the Bosc pears (Orchards 1-4) resulted from earlier storms, and Bosc pears may have been more resistant to infection by August when the infections in the DeVoe pears presumably occurred. Alternatively, DeVoe pears may be more susceptible to infection than Bosc pears under conditions that are only marginally favorable for infection.

Effects of rapid temperature declines on infection by *E. amylovora* should be explored further to determine if the same phenomenon occurs with apple fruit or with pear and apple leaves or shoots. Leaves and terminal shoots of apples and pears become resistant to infection when terminal growth ceases (9). Dry conditions during early summer contributed to early cessation of terminal shoot growth in the orchards that we observed in 2002, so leaves were no longer susceptible to fire blight infection at the times when temperature declines contributed to fruit infections. However, if similar storms occurred earlier in the season while terminal shoots were still actively growing, then temperature declines could conceivably contribute to fire blight infection of leaves and shoots.

If irrigation with cold water on hot days contributes to fire blight infection of apple fruit or foliage, then evaporative cooling of apples might contribute to the spread of fire blight in apple orchards where *E. amylovora* is already present. Evaporative cooling is used in some climates to decrease damage from sun scald, and it is usually initiated only when air temperatures reach a critical threshold (6). Starting evaporative cooling earlier in the day before fruit become hot might reduce the potential fire blight risk associated with rapid cooling.

Based on this work, pear growers should be advised to avoid initiating overhead irrigation during periods of extremely high temperatures. However, there are no simple solutions for controlling fruit infections that might occur as a result of storm-related temperature declines. Applying antibiotic sprays ahead of storms is impractical because summer thunderstorms are usually scattered and follow unpredictable paths. Antibiotics applied after storms have occurred and after temperatures have already declined might fail to control bacteria that were drawn into fruit during the rapid temperature declines. Furthermore, additional applications of antibiotics during summer might accelerate selection for antibiotic-resistant strains of *E. amylovora* (4). Use of reflective particle films might help to minimize heat build-up in fruit (3), but effectiveness of particle films for preventing infection of pear fruit needs to be verified. The information reported here should help in understanding the spread of fire blight during summer and may eventually lead to other crop management solutions for avoiding fruit infections.

Acknowledgments

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