Pesticide applications can be reduced by forecasting the occurrence of fireblight bacteria

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Fireblight, caused by the bacterium *Erwinia amylovora*, is an erratic and devastating disease of pear orchards. Native to North America, it was first observed in California in the 1890s after slowly crossing the continent from the east, decimating pear orchards in its path. Fireblight has the potential to destroy an established orchard in one season if uncontrolled. With 37,440 acres of bearing trees producing a crop of 353,500 tons valued at $44 million, California pear producers have traditionally spared little in their protection efforts to keep the disease in check.

Blight "strikes" have been continuously and carefully pruned from diseased trees since fireblight first arrived in California. Chemical spray treatments, first used to control the disease in the 1940s, have been relied upon heavily, especially in the critical flowering period. Until recently, it has been common practice to spray or dust trees with copper or antibiotic materials at 5-day intervals throughout the flowering period, which could total as many as 15 or 20 applications per season. This procedure was followed regardless of whether or not the bacterium was present since there were no available techniques to monitor its occurrence.

Spraying with pesticides costs at least $8 per acre each time a chemical is applied. It became apparent that spray applications were frequently unnecessary because untreated orchards in certain years had few fireblight infections. Furthermore, continued usage of streptomycin is related to the development of resistant strains which are now common in California pear orchards. Fixed copper materials cause skin damage (russetting) on pear fruits, resulting in economic loss for the grower. Russetting is more severe when copper is applied during low temperatures during the period when skin development is minimal.

Many attempts have been made to relate disease incidence to factors such as winter and spring temperatures, moisture and humidity, prevalence of insects, incidence of holdover cankers, and fertilization regimes. However, lack of data on the occurrence of the bacteria prohibited the development of a usable forecasting system. A method was needed to monitor populations of the bacteria during the year—especially in flowers, since fireblight frequently occurs as blossom-blight in California.

Selective medium

In the late 1960s we began developing a selective, differential growth medium for the isolation of fireblight bacteria from pear flowers. The selectivity of the medium was based on the incorporation of thallium nitrate and several other compounds that were toxic to bacteria other than *Erwinia amylovora*. Although the medium is not exclusively selective for *E. amylovora*, most *E. amylovora* colonies can be identified directly on the medium because of distinctive characteristics. They are smooth, round, and orange-red, generally with a translucent margin. Although there is some variability in appearance, an experienced investigator can distinguish *E. amylovora* from the other bacterial colonies on the plate. Colonies of *E. amylovora* that grow on the plates are periodically authenticated by pathogenicity tests with immature Bartlett pear fruits, hypersensitivity on tobacco, and with an antiserum specific for fireblight bacteria.

This medium has been a key element in the development of a monitoring program that allowed us to correlate the occurrence of fireblight bacteria with weather. Solely by averaging daily maximum and minimum temperatures, growers can now predict the occurrence of fireblight bacteria and apply sprays only as necessary.

Fireblight ecology

Fireblight bacteria overwinter in cankers made by blossom infections the previous year on pear trees or other nearby host plants such as apple, quince, pyracantha, hawthorn , or crabapple. Since cankers may be small or without obvious symptoms, they are not always noticed. With warm spring temperatures bacteria ooze from the cankers and are disseminated to flowers by water and insects. During one epidemic, it was found that the insects in an orchard (principally several species of flies) were very effective inoculating agents, carrying up to 100,000 cells of the bacterium per insect (fig. 1).

New infections in pear trees usually begin in the highly susceptible flowers, although leaf and twig infections are occasionally seen. Since the Bartlett pear often has a long, irregular bloom period in California, the critical time for infections may extend for many weeks, even months. After primary bloom is over, secondary "rattail" flowers can appear all summer long and can serve as infection sites.

Insects, mites, wind, and rain help disseminate the bacterial cells from canker surfaces onto nearby pear flowers, and from infected and infested flowers to other flowers. Although the bacteria multiply on the flowers, they do not necessarily invade and infect the plant until there is rainfall, dew, or periods of high humidity coincident with susceptibility of of flowers. During cool spring conditions, bacteria may not be disseminated from holdover cankers to blossoms until well past the main bloom.

Monitoring procedures

To monitor flowers, a bulk sample of 200 flowers was collected at random twice each week from a 5-acre area. The area included those parts of the orchard that were most likely to be blighted. Collected blossoms were kept on ice until processed (preferably within 4 hours). Tap water was added to the bulk sample in the original, clean polyethylene collection bag at the rate of 0.5 ml/flower; then the sample was shaken for 30 seconds. A 0.1 ml sample of the original wash

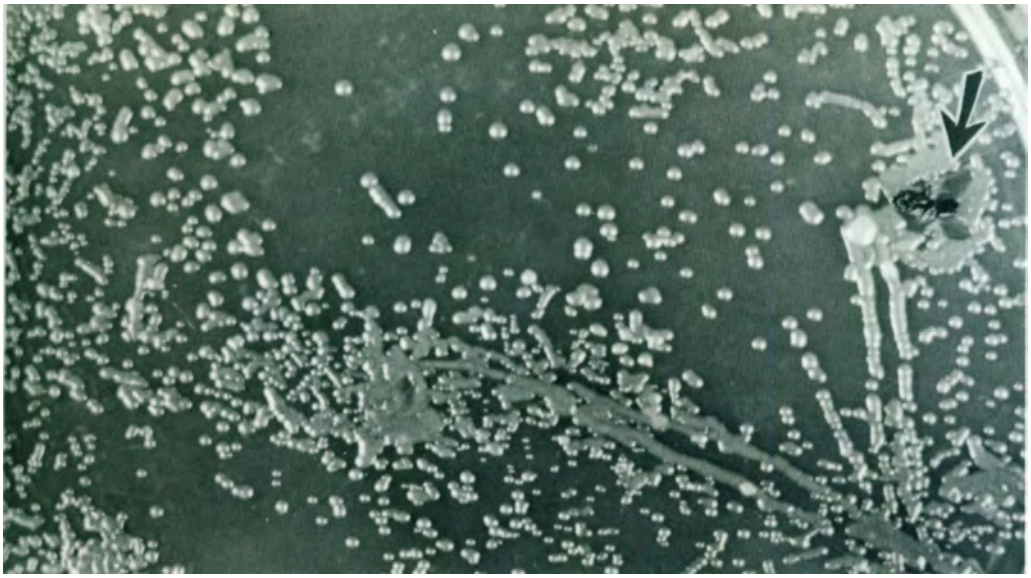

Fig. 1. Colonies of fireblight bacteria from a fly captured in a pear orchard. The insect (arrow) was placed alive in the Petri dish and distributed the bacteria by walking over the medium.

water was thoroughly spread on a Petri plate of the selective medium. A 1:100 dilution was made from the original wash water, and 0.1 ml of this dilution was spread on another plate. The plates were incubated at 28°C (83° F) for 48 to 72 hours; then the number of *E. amylovora* colonies were counted.

It is assumed that each colony is derived from a single bacterial cell which was washed from a flower. Therefore, a colony count gives an accurate count of the number of bacterial cells per pear flower. Blossoms can be washed and plated in the field with minimal contamination.

The farm advisors or their assistants who sampled flowers also recorded daily weather and tree-growth data. The plated samples were incubated and analyzed for *E. amylovora* colonies at UC Berkeley, so that data would be consistent. Plates were read about 3 days after sampling. A weekly compilation of findings from the various monitored regions was sent back to the farm advisors.

Findings

The most important finding from the monitoring studies was that fireblight bacteria could be detected in flowers 3 to 45 days before the appearance of blight in an orchard. During 1973 to 1976, the bacteria generally were found only late in the season during secondary (rattail) bloom. In some districts, blight bacteria were not detected in flowers throughout the entire flowering season, and blight did not appear in the orchard.

Although it is necessary for bacteria to colonize flowers for infection to occur, bacteria were often found in flowers without infection occurring. No doubt infection requires certain environmental conditions in addition to the susceptibility of the flower.

Using 6 years of monitoring data from over 120 orchards representing the major pear-growing areas in the state, we have developed a formula to predict when fireblight bacteria are most likely to colonize pear flowers. Consistently, bacteria are first detected after the daily mean temperature in the orchard (average of high and low temperatures from midnight to midnight) exceeds temperatures delimited by a line drawn from 62°F on March 1 to 58°F on May 1 (fig. 2). For example, in a Glenn County pear orchard, bacteria were detected in the blossom wash on April 21, 9 days after the mean temperature had exceeded the prediction line on April 12 (fig. 3). Note that *E. amylovora* was detected in flowers at petal fall, after full bloom. Fireblight strikes, first observed on May 4, averaged only 0.1 per tree.

In a few orchards, *E. amylovora* was not detected until approximately 2 weeks after the mean temperature exceeded the prediction line (fig. 4). There were few overwintering cankers in these orchards and thus bacterial populations took longer to multiply to a detectable level.

If the mean temperature exceeds the prediction line during a period of heavy bloom, it is likely that the orchard will be severely infected, especially if rain occurs during this warm period. For example, in a Yolo County orchard in 1976, the mean temperature exceeded the prediction line on March 16 during 1 percent bloom, and it rained on March 18 and 19. *E. amylovora* was detected in the flowers on March 25 with the population remaining high during the full bloom period; strikes averaged 1.5 per tree, with the first infections noted on April 27 (fig. 5).

Historically, blight has been severe when warm temperatures and rain occurred during full bloom. For example, in Mendocino County in 1961 (prior to the development of the monitoring concept), the mean temperature exceeded the prediction line during full bloom, coincident with rain; consequently this was one of the worst blight years on record.

Control

In the past, bactericides were applied at 10 percent bloom and every 5 days thereafter, a procedure which gave excellent fireblight control. Our approach was to apply sprays only after the mean temperature exceeded the prediction line This too gave excellent control. For example, in a pear orchard in Davis, applications were reduced from 14 to 6 with no significant difference in fireblight control (table).

In 1975 and 1976, growers obtained all the benefits of delayed and reduced spray applications, and saved approximately $750 thousand per season by following these guidelines. In 1977, however, most pear growers were required to begin sprays during full bloom because of early warm temperatures, and such savings were not realized with the new method.

The mean temperature can be easily obtained with an inexpensive maximum-minimum thermometer. Recording thermographs placed in each orchard will allow even more precise predictions.

The use of the daily mean temperature to predict the need for bactericide applications is conservative and in some cases they may still be applied needlessly before *E. amylovora* are present in flowers. Other temperature or environmental parameters might predict the need for bactericide applications more accurately than does the daily mean temperature, and we are now analyzing the ac-

Fireblight Control in a Davis, California Pear Orchard Comparing Normal Bactericide Application Procedures with Delayed Applications Based on Mean Temperatures

	Number of bactericide applications	Fireblight infections/ tree
Normal*	14	0.3
Delayed†	6	0.2

*Normal applications of a fixed copper bactericide were initiated at 10% bloom and continued every 5 days until rattail.
†Applications of streptomycin were not initiated until the mean temperature exceeded the prediction line (see fig. 2).

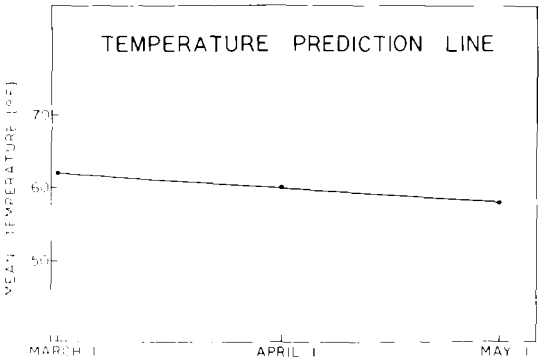

Fig. 2. Populations of *Erwinia amylovora* during bloom are usually detected in flower samples taken shortly after the mean temperature exceeds the prediction line; bactericide applications should then be initiated.

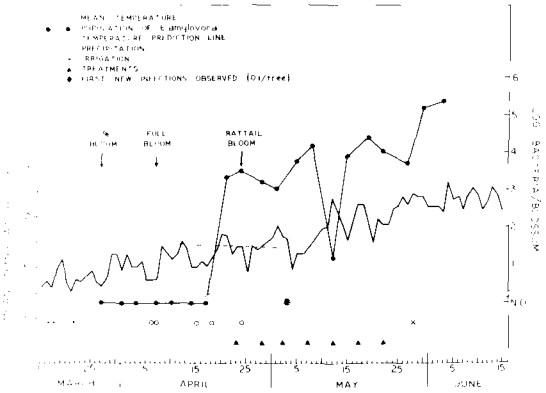

Fig. 3. Monitoring record for populations of *Erwinia amylovora* in pear flowers in a Glenn County orchard, 1975.

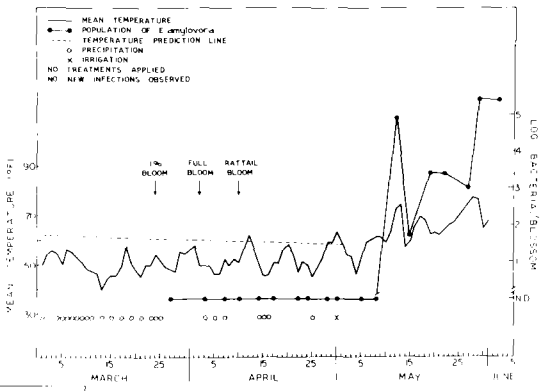

Fig. 4. Monitoring record for populations of *Erwinia amylovora* in pear flowers in a Sacramento County orchard, 1975.

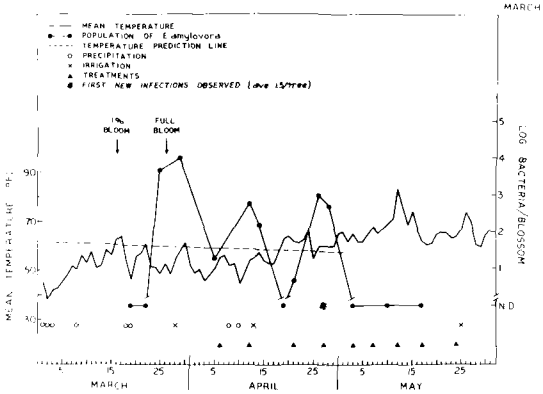

Fig. 5. Monitoring record for populations of *Erwinia amylovora* in pear flowers in a Yolo County orchard, 1976.

cumulated data by computer to provide a more accurate prediction method based on other environmental parameters in addition to the mean temperature.

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Codling moth, *Laspeyresia pomonella* (Linn), is one of the most serious pests attacking walnuts. Yet many growers and researchers have observed that certain walnut varieties are more susceptible to codling moth damage than others.

Of the old standard varieties, Payne and Concord have proven to be the most susceptible to codling moth damage, while the Franquette and most other late varieties generally escape damage caused by this insect.

There is no evidence of any walnut variety having an actual resistance to codling moth attack, although shell characteristics, such as seal, may be of some importance in warding off codling moth damage to kernels.

Pubescence on the developing nutlets may serve as a repellent against the egg-laying activity of the first brood of codling moth, since female codling moths prefer smooth surfaces for oviposition rather than rough, uneven,textured surfaces. Pubescence on the nutlets is lost on most varieties as the nutlet grows, but on some varieties, such as Hartley, this pubescence remains until the nutlets are quite large. Leafing date and fruit development characteristics seem to be important in escaping attack from this pest.

Trial

The purpose of this trial was to compare the susceptibility of many of the newer walnut varieties to codling moth damage when exposed to the same population levels of codling moth.

A trial consisting of ten walnut varieties, which received no chemical control of codling moth, was established in 1974 in a 12-acre walnut variety plot