Questions that need answering regarding Fireblight that should be taken in consideration of the current IRA 2004 from Biosecurity Australia

Preamble
The surmise that: "It is the job of Biosecurity Australia to arrange the least restrictive trade route to allow trade to take place" or "It is the job of Biosecurity Australia to keep pests and disease out" I don't see how it can do both . If it is the former all questions are directed to "how do we overcome quarantine restrictions that are currently imposed" and if it is the latter the questions revolve around "how do we continue with strong barriers to prevent the entry of pest and disease".
Does a policy statement come from the minister of trade that "we wish to allow trade in this produce" Take all steps necessary to allow this to happen and direct resources toward this end .It should be "find all the science we need" to continue to restrict trade in this product as the risk of disease is too great!

The first question I have is "Why in the formation of the RAP was Dr. Chin Gouk not chosen"? As she is an internationally recognised expert on Fireblight and is currently working within Australia? Was it because it may cause alarm from within industry as she was formally from New Zealand an had worked on fireblight there for 10 yrs ? I feel this question should be posed to Biosecurity Australia. Dr Gouk has presented a number of papers on the subject and they have been reproduced in "Acta Horticulture" so her credentials are second to none of researchers currently within Australia.

On the subject of counter measures, clearly some of them are laughable, the storing of the fruit for a period of 6 weeks would have no effect on the killing of the disease at all . It is common knowledge that the cultures that scientists use for trial work in relationship to Fireblight is kept in refrigeration around 5°C so it is hardly likely that a lowering of the temperature to 0°C would have such a dramatic effect on its status. One would also have trouble believing that the temperature of 0°C would have an effect on the bacteria as in the natural environment in some states of America the temperature often falls to -25°C and in Europe the temperature would travel lower again. I would like to quote from the last IRA draft Dec 1998 page 15 where in the 2nd paragraph "for example *Scholberg* et al (1988) found that *Erwinia Amylovora* survived for many months in cold storage
The severity of the northern winter temperature seems to have no effect in nature on the ability of Fireblight to survive and cause outbreaks though it may in the lab under certain controlled conditions.

The suitability of the information that gives us the storage method of control does not delve into all the differences between natural occurrences of *Erwinia Amylovora* and the cultures used in trials. This has not been taken into account in especially for some of the published works used for this IRA.

Critical Comment: It is OK in some studies to use diluted inoculum because the bacterium had the time to grow and multiply under normal condition. However, the quality of inoculum is still important. In the chlorine and cold storage papers (or any mature apple experiment), mature apples were inoculated with a diluted bacterial suspension and then subjected to treatment. It is not the same as when the inoculum had the chance to multiply on fresh stigmas under warmer temperatures for several days, the bacteria would have been able to establish and be better protected with polysaccharide coating.

## *Symptomless - mitigations- survival - cold treatment - exposure*

As a result of the meeting attended with Biosecurity Australia in June 04 in relation to the "symptomless orchard". A question on "If a grower goes out and cuts off the infection prior to the orchard inspection," (Biosecurity Australia's reply) is prepared to say it is "free of disease".
. I believe the statement to be wrong: *if fireblight is detected the season before or at any time during the season, the block should be out of the program for this year and the year following so for a total of 2 years. This is important as it relates to the position on whether the fruit is infected or infested .If fruit is from a symptomless orchard it is just as likely to be infected as it is to be infested for the reasons set out here*

- Researchers have shown that *"Infection and dissemination of inoculum logically takes place well before symptoms are expressed" (Thomson 1986, van der Zwet's book 1979, Thomson 2000 life cycle). Maryblyt - Paul Steiner 1989 suggested that blossom blight symptoms takes 7-14 days to express, shoot blight symptoms 10 - 35 days, depending on temperatures. If rain occurs before symptoms are removed, inoculum would have been spread. Also Erwinia Amylovora can move internally to infect new shoot tips without showing symptoms.*

- “Where highly susceptible apple rootstocks (M.26, M.9) become infected, much of the scion trunk and major limbs above the graft union **very typically remain symptomless**, while a distinct dark brown canker develops around the rootstock. As this rootstock canker girdles the tree, the upper portion shows symptoms of general decline (poor foliage colour, weak growth) by mid to late season. In some instances, the foliage of trees affected by rootstock blight develop early fall red colour in late August to early September, not unlike that often associated with collar rot disease caused by a soilborne fungus. Some trees with rootstock infections **may not show decline symptoms until the following spring,** at which time cankers can be seen extending upward into the lower trunk. Where highly susceptible apple rootstocks (M.26, M.9) become infected, much of the scion trunk and major limbs above the graft union very **typically remain symptomless**, while a distinct dark brown canker develops around the rootstock. As this rootstock canker girdles the tree, the upper portion shows symptoms of general decline (poor foliage colour, weak growth) by mid to late season. In some instances, the foliage of trees affected by rootstock blight develop early fall red colour in late August to early September, not unlike that often associated with collar rot disease caused by a soilborne fungus. Some trees with rootstock infections may not show decline symptoms until the following spring, at which time cankers can be seen extending upward into the lower trunk.”
  Professor P.W. Steiner, University of Maryland, and A. R. Biggs, West Virginia University 1998

- Blossom blight symptoms most often appear within one to two weeks after bloom and usually involve the entire blossom cluster, which wilts and dies, turning brown on apple and quite black on pear. When weather is favourable for pathogen development, globules of bacterial ooze can be seen on the blossoms . The spur bearing the blossom cluster also dies and the infection may spread into and kill portions of the supporting limb. The tips of young infected shoots wilt, forming a very typical "shepherd's crook" symptom. **Older shoots that become infected after they develop about 20 leaves may not show this curling symptom at the tip”** Professor P.W. Steiner, University of Maryland

- **“2.1 Overwintering Sources of Inoculum.** The pathogen overwinters in living bark tissues surrounding some cankers formed at the base of spurs or shoots killed the previous season. They can also form in the bark surrounding cuts made to remove infected shoots during the growing season. There are two types of cankers: determinate and indeterminate. Determinate cankers have strongly delimited margins, often marked by a distinct crack or separation of the bark caused by an effective, early season resistance mechanism in which a barrier of suberised, corky tissue isolates the pathogen from the surrounding healthy bark tissue. Determinate cankers seldom serve as sources of inoculum the following season. Indeterminate cankers lack this physical barrier zone so that their margins usually appear smooth and continuous with the surrounding healthy bark surface. Here, damage caused by the bacteria in the intercellular spaces withdrawing water from healthy cells appears to be halted only by the high carbohydrate reserves that develop in the bark during the mid- to late- season (e.g., after mid-June). The bacteria do not overwinter in the dead tissue of indeterminate cankers but in the living bark tissue that surrounds them.” Professor P.W. Steiner, University of Maryland

- “One reason for this is that even before shoot tips wilt, droplets of bacterial ooze are often present on otherwise symptomless shoots and these are sources of inoculum for further dispersal.” Professor P.W. Steiner, University of Maryland

- “At the same time, *there is mounting evidence that gusty winds may cause small injuries to tender shoot tips through which bacteria on their surfaces may then enter and initiate infections*. From a timely control program, this presents two problems. First, streptomycin has proven to be ineffective in preventing shoot tip infections and most copper formulations have the potential for phytotoxicity. Secondly, even if a good bactericide becomes available, it hardly seems practical to try spraying whole orchards every time the wind blows with gusts more than 8 to 10 mph between petal fall and terminal bud set”. Professor P.W. Steiner, University of Maryland   note to the timing of this –petal fall is often in late October and terminal set is as late as end of January.

- How the cuts are made is also important and has a substantial amount to do with how much carryover inoculum will be available the following year. Conventional recommendations often suggest that cuts be made 8 to 12 inches below the leading edge of symptoms and that cutting tools be surface sterilized with copper materials or alcohol between each cut. We've found the bacterial pathogen **as far as 9 feet back** on a branch with a single terminal shoot tip infection. This is far beyond the limit where most growers want to or is necessary to cut. In addition, because the bacteria are already internal in the infected limb, the sterilization of tools between cuts is of little practical value. Professor P.W. Steiner, University of Maryland

With all this evidence in mind how will a "symptomless orchard" be free of the disease, as required in the protocol for "disease free areas of production"?

- "Since many of these cankers are established later in the season, they are not often strongly depressed and seldom show bark cracks at their margins. Also, they are often quite **small**; extending less than one inch (25 mm), with reddish to purple bark that may be covered with tiny black fungus fruiting bodies (most notably *Botryosphaeria obtusa*, the black rot pathogen of apple). This brings us to a point of how effective the "orchard inspections are likely to be .We know the Japanese protocol had 3 inspections each year in New Zealand and found quite a change each time they had inspections done .The results of these inspections were such that the shipment of fruit eventually stopped as it was not possible to clearly keep the blocks "disease free area's of production" ,which is the term under which I believe we operate as well under the WTO .

- The level of orchard inspection is of grave concern. If, as has been said by Biosecurity Australia that it has " no intention of inspecting every row of every orchard"(comment at the Melbourne meeting with industry in June 04 ). How can one say it is free of visible symptoms? And one may ask how often during the season it should be inspected, as well as when . In the years that New Zealand traded fruit to Japan the level of inspection was at 3 times during the season in the orchard .The records show each time they inspected blocks listed for export they took orchards out of the program It is recorded that from the first to the final inspection that in some years over 50% of blocks failed and more particularly when MAF Japan inspectors were themselves involved physically in the inspection, more blocks failed, than when the New Zealand teams inspected the blocks .This worries me more as to the competence of the New Zealand inspections. This in itself is strong evidence that even with orchards considered being 'disease free', the disease develops at some stage. We should have the ability to have further inspections if severe wind events occur late in the season .
- "Canker blight symptoms are often overlooked in the light of much more numerous and dramatic blossom infections or because of their similarity to the more familiar shoot tip (=shoot blight) infections that occur later. Because of the limited number of overwintering cankers in a well-managed orchard the significance of canker blight is often underestimated. Indeed, their importance is probably insignificant in terms of overall damage when blossom blight occurs. However, in years when blossom infection events do not occur or have been well controlled, active canker sites serve as the primary source of inoculum for a continuing epidemic of secondary shoot blight infections that can lead to major limb, fruit and tree losses. Such sources of inoculum can also be important for new orchards with no history of fire blight when they occur in older, surrounding orchards from which the bacteria **can be moved into young orchards by wind, blowing rain and certain insect species."** Professor P.W. Steiner, University of Maryland with this in mind it further show the need for multiple visits to orchards and the need for trees at the edge of "blocks destined for export to Australia" to be also free of the disease as to the ease of transmission of bacteria to trees and fruit

There is another question of selective reporting, which occurs in a range of places in the document I give an instance of one occurrence of this.

- The statement on pg 114 on the research that Ceroni et al did in 2003 "*Erwinia Amylovora* can survive on artificially contaminated wood for limited periods, but transfer from there has not been demonstrated on uninjured fruit". It beggars belief to say anything of the sort, as the trial quoted did not do any work to test the theory on the transference of the isolate to fruit. It also strikes me as odd to say "for a limited period " when we are talking about a period of up to 101 days maximum as was demonstrated in the trial in question. I certainly thought that the use of the words "limited time" implied a much shorter time span. So in fact the quote should stop at the word "wood" or read "*Erwinia Amylovora* can survive on artificially contaminated wood for up to 101 days". What it can do in the natural environment is entirely up for question.

There is plenty of information that *Erwinia Amylovora* is more robust than is credited in the IRA . The talk given on The Biology and Epidemiology of Fire Blight Paul W. Steiner, presented at the Illinois Horticultural Society Meeting, January 2000 it is quite clear he has a very different view to Biosecurity Australia on the ability and the survival chances of Erwinia Amylovora in a range of conditions. I include a number of his talks as attachments at the end of this submission for perusal.

The next point is in regard to the "potential pathway". The ability to cross from apple to a host plant is in the IRA labelled in pg 97 sequence of events for successful exposure is listed as unlikely as there is *no known vector recorded of arthropods being shown to do so. I now would like to introduce some ***new science*** since the last draft of the IRA. There is now a paper to demonstrate that this is not only possible but it can be shown to do so in a similar bacteria and the work has been done on apples.

**TI: Fate of Escherichia coli O157:H7 on fresh-cut apple tissue and its potential for transmission by fruit flies.**
AU: Janisiewicz-WJ; Conway-WS; Brown-MW; Sapers-GM; Fratamico-P; Buchanan-RL
SO: Applied-and-Environmental-Microbiology. 1999, 65: 1, 1-5; 28 ref.

*Many insect vectors have been cited to assist in spread of fire blight. Whilst there have been no specific investigations into movement of *Erwinia Amylovora* by insects from discarded apples, the pathway has been demonstrated with another bacterium, *E. coli*.

*E. coli* is a not a plant pathogen. That it can survive and be transferred by fruit flies visiting apples in a compost heap provides the evidence for similar transfer pathway for fire blight.

And another paper to offer the possibility of transfer pathway for bacteria to be taken into internal tissues of apples.

**TI: Internalization of Escherichia coli in apples under natural conditions.**
AU: Seeman-BK; Sumner-SS; Marini-R; Kniel-KE
SO: Dairy,-Food-and-Environmental-Sanitation. 2002, 22: 9, 667-673; 20 ref.

Now I will show that, having a potential pathway, I have opportunity to pass the pathogen to a host plant nearby.

- In table 27 there is the mistake in wholesalers proximity, as I personally know that 4 of the 5 wholesalers that supply the Woolworth's chain in Victoria with apples. I have found the maps of Melbourne (Melways 2002 greater Melbourne) pgs 2t -Melbourne wholesale mkt and a transfer waste station within 2 km ,as well as metropolitan housing within 2 km . map 108 Montague's packing shed and orchard on Horswood rd is within 3 km of waste station on map 83 (h7) ,M Ajani's shed and orchard is on map 215 b1 is within 2 km of residential housing on map 214 (officer),Michael Napoleon's shed and orchard is on map 119 and the Lilydale transfer station is within the 4km range on map 281,f 12. All these sheds are likely to handle fruit from New Zealand especially if it comes loose in bins for repacking. All of them are major suppliers of one of the major chain stores here in Australia. All of them have the opportunity to have industrial accidents where fruit may be discarded in large qty on the orchard itself or be transferred to the local waste station. Other opportunities arise including the opportunity for apples discarded on roadsides to transfer to trees on the road verge of which there are many chances. Proximity and exposure are grossly under estimated we should stress that the use of hypothetical scenarios is flawed when the facts show the opposite. This would be the case not just in Victoria but in Sth Australia as well.

Next I would like to highlight the volume of potentially infested fruit in the next few years and the indication of how long at the numbers that are in the IRA before an outbreak is likely to occur .It really is a case of **when** not if. If we use their own numbers of between 0.5% and 1.3% (pg 89) the number of fruit that is infested ***will be between 1 million and 2.6 million pieces of fruit annually (based on import volume of 200 million apples)***. * In Clark et al. (Acta Hort. 1993), 87% of the calyx were infested in a studied block in New Zealand. The number of infested fruit imported would be much higher if higher levels of infestation occurred in the orchard. In the IRA we constantly see the expression of the words "single apple" appear as the potential source, when in fact we are talking of over a million of pieces of fruit each year.

It is also interesting that according to the model, if modelled over time, the risk reaches the highest level in as short as 10? Years. Certainly not a long time frame as calculated by R. Roberts of USA.

Other considerations to be covered

- If Biosecurity Australia considers the bulk shipment of fruit how will they sample the fruit at the bottom of fruit bins that are 75cm deep in apples, where generally the trash will fall in transit?
- Again if bulk shipment is to be considered the opportunity for waste to arrive on an orchard is more easily demonstrated as it is likely to go to an orchard for packing. How does this affect the exposure risk
- If chlorine is to be used, all packinghouses will have to be registered for packing to allow for inspection .I note that there is talk of high pressure washing of apples. Is this to be mandatory? It does not state this in the IRA and yet it talks about the benefits of this. Yet there are a number of papers that refute the idea of being able to wash bacteria off apples and these are listed in the paper Kenny et al on the "location of Escherichia coli on and in apples as affected by Bruising, Washing and Rubbing" Journal of food protection, Vol 64,no 9, 2001 pages 1328-1333)
- I note the talk of cleaning the water in the dump tank after 600 bins. This clearly is a joke as the first bin may be the one that is carrying contamination. From personal experience after 75 bins the water is already carrying a significant number of other fungal diseases for which we treat in any case by changing the water at this time in our own operation .One would expect that fruit destined for Australia would be run through a separate system to other fruit to avoid cross contamination.

In another part of the document Biosecurity Australia talk about undamaged fruit and how Erwinia Amylovora will not affect it. Well, we know from a paper that as fruit is effected by the packing process and that minor cuts and bruising marks occur, (Kenny et al) if so, on a bacteria such as Escherichia coli also to survive a "A wide range of methods of chemical washes, high pressure sprays and brushing, have been proposed to clean and sanitise apples. However no single method is effective in completely removing bacteria from apples indicating that pathogens may adhere to or colonise in structures or tissues on the apple surface, where they are protected from decontamination treatments", (Kenny et al) it is possible for the similar bacteria *Erwinia Amylovora* to enter the small cracks in the fruit skin and survive. How does the IRA make the point of fruit not managing to transfer the *Erwinia Amylovora to* all the other fruit in the system at the time of packing?

I also include a copy of 2 studies of bacteria build-up in water tanks after fruit throughput. . Holmes, and Sanderson (attached). Both of them basically show the more bins you put through solution the higher the load of contaminants in the solution. This makes me wonder seeing the load of contaminants in this study how Biosecurity Australia suggests that the water be cleaned every 600 bins .We know from the studies that the addition of extra chemicals in the process does not lower the spore load in the solution. For some apple cultivars with open floral tubes, the cold-water wash actually help ingress of bacteria into inner core. I think the condition; "mouldy core" of either Braeburn or Pacific Rose is caused by the floral tube failing to close up.

Biosecurity Australia then go onto say that in export packing houses that the machines are cleaned at the end of the seasons so they would not have any contamination in them. I wonder if any tests have been taken on them to prove this conclusion. When we pack here in Australia we have to clean down the entire machine at the end of each week for our SQF procedure. and we do not test for bacteria .

- On page 97 in the second paragraph from the bottom, there is cause to be concerned as now we have demonstrated in the attachment (Janisiewicz-Wj et al) I have supplied, on the recent American work on e coli, we now have a clear pathway for the spread from the apple to a possible host! is this not so ?
- In table 27 there is the mistake in wholesalers proximity, as I personally know that 4 of the 5 wholesalers that supply the Woolworth's chain in Victoria with apples, all have orchards in extremely close proximity to their shed and packinghouse less than 50 Mts. So the very one where most of the fruit may end up in after distribution from the docks area is the one area most likely to

be involved with waste and fruit trees at some stage. It also changes the risk status of the matrix as we have the potential to shift the risk from negligible to low.

- The information supplied often refers to a single piece of fruit being discarded. if it was at a commercial wholesalers premises there would be an opportunity to encounter a lot more waste than that . In most repackaging arrangements a large % of fruit is. If fruit is rejected from a chain store we often discard up to 20% of fruit, of which 10-29% of this is thrown out to waste. It is only the fruit from rejections from supermarkets that we are talking about at this point. If we are talking about loose fruit, up to 50% of fruit may be discarded in some extreme cases. In the more common case around 20% of fruit is discarded and of that, perhaps 5-25% is waste .If fruit arrived loose in bins the potential for greater losses is possible .We have had the occasion where fruit is tipped over when unloading takes place, or bins become broken during transit and the fruit is rolling around the truck .all this fruit is liable to damaged in some way .A percentage of this fruit is always going to be contaminated (figures from the IRA ) and it is likely this fruit will not be collected in the usual manner and disposed of in a dump master .it is likely to be swept up off the concrete and pushed off to one side and left to rot .ample opportunity to set the possibilities in place for transference especially at one of the orchard packinghouses .

The next one is that most of the time Biosecurity Australia talk about the host plants not being in blossom. But what they forget is that the fruit harvest is almost 6 months into the next season and after, the storage regime they suggest in the document, it would be now in the period of time coming up to flowering time in the spring. This is the time of most risk and it will coincide with the arrival of most of the fruit from New Zealand and from the distribution points back to either the packing houses or shops in the outlying areas of metropolitan areas and hence pose the most risk.
Plus how long will the apples be around until they are discarded? Also ornamentals would flower at different time and extend the period of susceptibility. Epidemics in nurseries do not require flower for infection to spread. Injury to plant tissues is sufficient for entry of the bacterium.

Another problem we have had with the process is the manner in which the consultation meeting s with the stakeholders have taken place in the last month since the IRA's release .The meetings with Biosecurity Australia have been structured by Biosecurity Australia to allow the growers to moan as much as they like and Biosecurity Australia is not going to take any notice of anything that comes out of the meetings .The meeting that I attended I did ask if there was anyone to take notes .The chair of the meeting suggested that they(Biosecurity Australia ) were not taking notes as they had no need to do so, as any issues that were to be raised at the time were the responsibility of the attendee's, to bring them up in their own submissions to Biosecurity Australia .I found this to be rather foolish or was it a point of them not about to take any notice of pertinent questions that were not able to be answered at the time . I would like to draw your attention to one of them. The questioner asked "if after the shipment of fruit from a block of an early variety (eg Gala) left New Zealand what would happen if they found fireblight in the block in another inspection for a later variety". There was no clear answer from the Biosecurity Australia panel assembled, as they had not thought of this happening.

This concludes my submission and I thank you for the time

Kevin Sanders
Vice Chairman APAL
Chair: Horticulture Australia / APAL IAC R&D committee
Fruit Grower in The Yarra Valley Victoria.

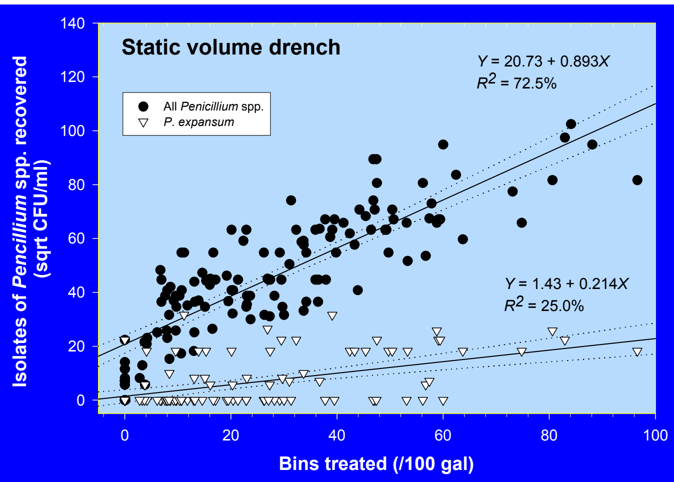


Fig 1 Accumulation of all *Penicillium* and *Penicillium expansum* in DPA drench (Peter G Sanderson)

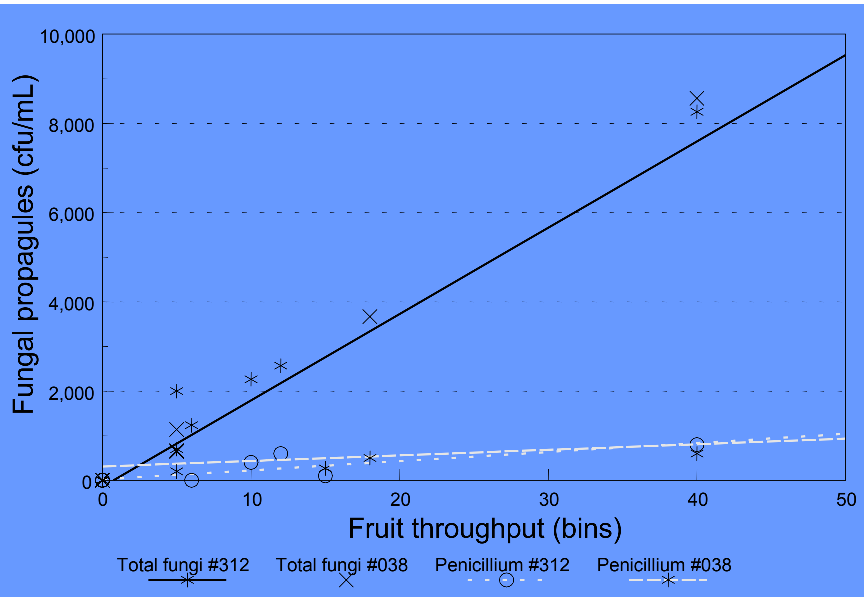


Fig 2 Accumulation of total fungi and all *Penicillium* in two flotation tanks (shed #312 is Sanders, shed #038 is Burgi)

# HORTICULTURE

This is the original report posted in July of 2000, compare with the final report

## The Fireblight Epidemic in Southwest Michigan

Mark Longstroth

Summary: Southwest Michigan apple orchards suffered severe fireblight damage this spring following unusually warm, humid, and wet weather in May. Fireblight is a highly contagious disease of apples and pears caused by a plant-eating bacterium. Heavy rains, often with hail, dispersed the disease throughout the apple growing region intensified the threat to the area's apple-growing industry. The fireblight epidemic in Southwestern Michigan is as severe as anyone can remember. Many acres of high-density apple orchards have been destroyed with the death of almost all the orchard trees. From 350,000 to 450,000 apple trees will be killed and 1,550 to 2,300 acres of apple orchards will be lost. The development cost of these orchards was over $ 9 million. Apple yields will be reduced by 35% over the region. Some growers will suffer 100% losses in some plantings. The Southwest region produces an average of 4.5 to 7 million bushels and the expected crop loss is 2.7 million bushels about $ 10 million. It will take at least 5 years for yields to recover with a cumulative loss of yield of nearly $ 36 million. The region's total economic loss is almost $ 42 million.

This four year-old Gala orchard will surely die.

Attempting to remain competitive, orchardists replaced outdated mature orchards to high-density systems. Many of the new premium varieties that were planted such as Gala, Fuji, several strains of Jonathan and Rome, and others were all susceptible as were the dwarfing rootstocks they were planted on. Now fireblight is destroying the investment and effort of the past decade.

The apple industry in Southwest Michigan will likely never be the same. The perfect blight conditions of 2000 occurred previously in 1991 when the industry was less vulnerable. It will be very difficult for apple growers to learn to manage fireblight given the current lack of premium fireblight resistant varieties. In addition, strains of the fireblight bacterium resistant to streptomycin are widespread in Van Buren County and were detected in orchards in neighboring Berrien County this year. Streptomycin has been the single bullet for fireblight control and it will be several years before chemicals in the registration pipeline will be available to replace it. Orchards can get through average blight years with existing controls, only to sustain devastating losses in 5 to 10 years when perfect fireblight conditions occur.

Improving current blight susceptible varieties through genetic engineering shows considerable promise for the future, but the public's negative view of genetically altered crops will need to be overcome before orchardists can utilize this new technology. The new blight-resistant rootstocks from conventional breeding will help growers most years, but only resistant varieties combined with resistant rootstocks will allow growers to avoid losses in perfect blight-favorable years such as 2000.

## Introduction - What is Fireblight

Fireblight is caused by a bacterium harmless to humans. It is a highly contagious and deadly disease of apples and pears. Fireblight attacks blossoms, leaves, shoots, branches, fruits, and roots. Initially the disease often enters the tree through flowers during bloom. Once established in the tree fireblight quickly invades through the current season's growth into older growth. Death of infected branches is so rapid that the leaves do not have time to fall off the tree. Young non-bearing and newly bearing trees can easily be killed by the infection while mature bearing trees may survive even if all the new growth is killed. Heavy rainstorms can spread blight and result in what is known as "trauma" blight. One infected tree adds bacteria to local rainfall in frequent summer storms further spreading the disease. For more information see the Fireblight Articles at the University of West Virginia.

Antibiotic sprays applied during bloom are used to control fireblight. A computer program called MaryBlyt is used to track disease development and time antibiotic applications.

Streptomycin, the most commonly used antibiotic for fireblight control, gives good control if used immediate before infection or within about 12 hours (24 hours maximum) after an infection. Oxytetracycline is used to control fireblight where streptomycin resistance exists. Oxytetracycline must be applied before an infection to be effective.

A mix of fresh market and processing apple varieties are grown in Southwest Michigan. Key apple varieties such as Gala, Idared, Jonathan, and Jonagold are very susceptible to fireblight; Golden Delicious and Romes are less susceptible; and a few such as Red Delicious are almost resistant. In order to preserve the economic viability of the Southwest Michigan apple industry, many new plantings of these varieties were established in the region during the last decade.

Apples are grown on rootstocks that increase the size and quality of the fruit and overall fruitfulness of the trees. Common dwarfing rootstocks such as Malling 26 (M26) and Malling 9 (M9) are very blight susceptible; they may even increase the susceptibility of the scion varieties. Rootstocks can become infected by direct infection of rootstock suckers at the base of the tree or when bacteria travel symptomlessly through the trunk into the roots. Infected rootstocks are quickly girdled killing the tree. Such systemic movement from a minor infection can result in tree death, even of resistant Red Delicious trees.

## The Size and Structure of the Southwest Michigan Apple Industry

| 1997 Southwest Michigan Fruit Census | | | | Michigan Apple % | |
|---|---|---|---|---|---|
| Crop | Farms | Acres | Trees | Farms | Acres |
| Apples | 447 | 17,000 | 2,500,000 | 35% | 29% |

This fireblight epidemic in Southwest Michigan affects primarily Berrien and Van Buren counties, the two largest fruit growing counties in the region. But other counties such as Allegan, Branch, Cass, Hillsdale and Kalamazoo and St. Joseph also have severely affected apple plantings. Today, in 2000, there are probably 6000 acres of apples in both Berrien and Van Buren Counties, 1300 in Allegan, and 2000 in the rest of the affected counties.

Southwest Michigan apple growers have suffered from poor prices for the last several years and many older growers have reduced inputs into their apple orchards by reducing pruning and fertilizing. The resulting trees have less new growth and are unlikely to suffer greatly from fireblight infection. While these trees are still vulnerable to infection it is less likely to cause tree death or dramatic yield losses. With reduced maintenance, yields and fruit quality on these trees declines. Growers who can not afford to maintain their orchards will not do the dormant pruning necessary to remove overwintering cankers that serve as the primary inoculum in the spring for fireblight. Reducing inputs is not a viable long-term strategy and these orchards soon fail.

The next step after reducing inputs is orchard abandonment. There are probably over a thousand acres of abandoned orchards in Berrien and Van Buren counties. These orchards have been abandoned or sold by their owners. In many cases the new owners are not fruit growers, but urban emigrants who desire rural land. They are unable to maintain the orchards and unwilling to remove the trees because of the high cost of removing fully grown standard apple trees 30 to 50 years old. These orchards serve as a reservoir for fireblight as well as other pests and diseases of apples and increase the costs and difficulty of maintain adequate disease management programs in neighboring orchards.

During the last decade, progressive Southwest Michigan apple growers have shifted from conventional plantings with 55 to 499 trees per acre to high density plantings with more than 500 trees/acre. These new high value plantings utilized increasingly popular M26, M9 and Mark rootstocks. There were approximately 1,500 acres of fireblight susceptible dwarfing rootstocks in Southwest Michigan in 1997 and new plantings on these rootstocks were being added at 100 or more acres per year. In 2000, there was a total of about 2000 acres of high-density plantings. There are 500 to 700 acres, which are 5 years old or less, which could be killed outright by fireblight. In addition, many older high density planting involving highly susceptible varieties will also be lost.

Apple planting in Southwest Michigan averages about 400 acres per year so that 2000 acres would be five years old or less. Most apples planted in recent years have been newer varieties such as Gala, Fuji, Braeburn etc. These varieties receive a premium price for fresh market fruit. The economics of the apple industry in the last several years have reduced profit margins to the point that large older trees are not profitable to maintain. To preserve the economic viability of their orchards, many of the top growers in the region have been busy replacing older plantings of standard and semi-dwarf trees with high-density orchards using dwarfing rootstocks. Yields of high quality fresh market fruit from these plantings quickly climbs to high levels that should be sustainable.

The remainder of the apple production in Southwest Michigan is processed into sauce, slices, and juice by area processors. Jonathan is preferred among all other varieties for the manufacture of frozen slices and Idared and Rome are preferred variety to manufacture apple pie slices and for use in applesauce. These varieties are susceptible to fire blight injury and subsequent tree death. In 2000, large blocks of these varieties suffered with severe fire blight.

Streptomycin-resistant fire blight was found in Van Buren County in 1990 and resistance had spread countywide by 1999. A few growers use a costly but relatively effective combination of streptomycin plus oxytetracycline, and these growers are more active in following MaryBlyt predictions in an attempt to apply treatments just ahead of an infection. Most other growers use less costly and weaker treatments of oxytetracycline, copper, or Aliette, or continue to use streptomycin despite resistance, or do not treat with any chemical. Where possible, treatments are applied before infection periods are predicted by MaryBlyt, but in practice are more likely to be applied after an infection. A few Van Buren County growers have avoided new plantings of fireblight susceptible varieties and susceptible dwarfing rootstocks. However, they have older fireblight susceptible plantings and are concerned about what varieties to plant in the future.

Many acres of high-density apple plantings have been severely affected by this epidemic. These orchards will be destroyed as economic units by the death of most of the orchard's trees. This epidemic will change the way we grow apples in Southwest Michigan. Few growers will again chance the risk of planting the new premium varieties hoping to maintain profits in a market with global oversupply, believing they could control fireblight. A major unanswered question is what varieties can be grown profitably in the future without undue fire blight risk.

## The 2000 Fireblight Epidemic

Because of the warm growing conditions in the spring fireblight is a perennial disease problem in Southwest Michigan. Growers typically apply 2 to 3 sprays of antibiotics during bloom and save the final spray for use after a hailstorm or other trauma. In Southwest Michigan the question is not will you have fireblight it is how bad will it be?

In 2000, fireblight symptoms began to appear in some Idared and Jonathan orchards several days earlier than predicted by the MaryBlyt model. Backtracking from the date of the symptoms indicates that the initial infections took place on May 7 and 8 when predicted bacteria levels reached record high levels. There was no rain or prolonged dew on these dates, but the average daily relative humidity values were 79.2% and 80.5%, respectively. Although rare in occurrence, infection can occur during dry periods when daily relative humidity values are above 70%. With minimum nighttime temperatures of 65 and 68 F, respectively, bacterial populations increased throughout each 24-hour period resulting in very high populations; populations that overwhelmed subsequent antibiotic treatments. Orchardists who applied antibiotics ahead of this weather achieved the best control. Beginning May 9, MaryBlyt subsequently predicted three infection periods associated with rain and favorable temperatures. Golden Delicious and Rome were in bloom and bloom blight was common on these varieties while all varieties suffered trauma blight from the heavy storms.

As the symptoms of the blossom and trauma infections began to appear, a cold front with wide spread hail and thunderstorms moved through the region on May 18. The blossom blight symptoms that began to appear in mid May appeared mainly in unsprayed blocks of susceptible varieties, and also in varieties such as Golden Delicious that do not normally get fireblight and were not sprayed. Fireblight strikes could also be found on varieties that are normally very resistant such as Empire, McIntosh and Red Delicious. This indicates we had extremely high levels of inoculum and good infection conditions. But the rainstorm on May 18 spread the disease though out the growing region. This large-scale weather event lasted for several days. It spread the disease to many previously uninfected blocks. Growers who applied antibiotics after rains were hard pressed to cover all their acreage within 24 hours. In addition this weather system spread the fireblight strains that are resistant to streptomycin to a large area where they previously where not found. It seems that were streptomycin resistant fireblight is found the use of streptomycin makes the disease worse because it removes competitors of the bacteria, which normally slow its spread. This means that the application of streptomycin actually increased the severity of the disease in some orchards.

This Jonathan orchard was found to contain streptomycin resistant fireblight.

At the beginning of June, another wave of fireblight symptoms began to appear in all susceptible varieties as a result of the trauma for wind heavy rain and hail. The symptoms from this infection are very severe and widespread. Most apple growers who planted new trees in the last five years will lose those plants. Others are concerned about the health of their older orchards. And all apple growers will lose a portion of their crop for the next several years.

## Loss Estimates

The Southwest Michigan apple industry will be severely affected for at least the next 5 years. Large portions of this year's crop have been lost due to the death of the branches and trees that supported the fruit. Many young orchards will need to be replanted; about 5 years will be required for these orchards to return to significant production. In mature orchards, 3 to 5 years will be required to grow new branches and restore production.

### Crop Loss Estimates for 2000

These Golden Delicious trees will probably survive, but they will lose most of this year's crop.

The Southwest Michigan apple crop varies from 4.5 to7 million bushels with a gross grower income of $ 30 to $ 40 million each year. Yield losses will probably be in the 20% to 70% range for most apple varieties. Some individual grower losses will be much higher. The total expected production loss for the region in 2000 is estimated at 2.7 million bushels, 113 million pounds. Using 9 cents as an average price per pound the total crop loss is $10 million. 2.7 million bushels or 113 million lb. at an average price of $.09/lbs. equals $10,179,000 loss. About 2/3 of the region's apple crop is processed and processing prices ranged from 4.5 to 9.5 cents/lb. in 1999. Fresh Market returns vary from 17 to 4 cents per lb. Returns depend on variety and grade and percent pack out.

**For 2.7 million bushel loss, Total Estimated Loss = $10,932,813**

Estimated Fresh market price of $.15 x 37,700,000 lbs. (1/3 of crop) = $5,655,000
Estimated Processing price of $.07 x 75,400,000 lbs. (2/3 of crop) = $5,277,813

## Accumulated five year loss of crop and income

The 2000 apple crop was expected to be off from previous years due to a heavy crop in 1999 and a severe frost in early April that probably reduced the 2000 apple crop by 20% or more. The part of the apple tree that was killed will not bear a crop next year. Apples bear their fruit on 2 year-old wood, so yields will not rise greatly until 3 years from now. If the tree is not killed it will probably be back to full production in 5 years. Losses in 2001 would be almost equal to 2000, then yield should begin to rise. For older trees (7 years or more) this increase in yield should end in about 5 years.

If the initial loss is about one million bushels the cumulative loss over 5 years will be about $ 15 million. For an initial loss of 2.5 million bushels then the loss will be $ 32 million. An average loss figure for the region would be $ 25.5 million.

## Estimated Tree and Acreage Losses for 2000

These young trees will certainly die

Young trees are very vulnerable to fireblight. I anticipate that most susceptible young trees from one to 5-years old will be killed in this epidemic. Trees from 5 to 7 years old will be severely damaged and many will die. Orchards that lose more than 20% of their trees are no longer economically viable and the orchard will need to be replaced. I do not believe that replanting into an existing orchard is economically viable once the orchard is more than 5 years old and the entire orchard or sections of the orchard should be removed. The extra cost of maintaining small trees in an older planting until they reach full size is not generally worthwhile.

I estimate the loss at 1550 acres, a lost investment of $9,300,000. I estimate that growers will lose; 720 acres of 1 to 3-year old trees; 240 acres of 4-year old trees; 251 acres of 5-year old trees, 165 acres of 6-year old trees, 120 acres of 7-year old trees and 46 acres of 8-year old trees.

Bill Shane has estimated the loss of 2,300 acres, a lost investment of $8,800,000. Bill estimates that growers will lose 500 acres of 1-year old trees; 800 acres of 2-year old trees; 375 acres of 3-year old trees; 200 acres of 4-year old trees; and 75 acres of 5-year old trees. Apple trees 6 years and older are estimated at a loss of 360 acres.

## County Loss Estimates

The following table estimates the acreage and crop loss for the major apple growing counties in Southwest Michigan. The acreage figures come from the 1997 Michigan Fruit Census. The actual acreage in 2000 was probably 2,000 acres less for the region. This reduced acreage is due to the removal of older processing blocks and old and medium aged trees of fresh market apples which where not profitable in today depressed world apple market. Some of the processing acreage would have varieties susceptible to fireblight but most of the fresh market acreage would have been Red Delicious a variety that is very resistant to fireblight.

| Apples: | Berrien | Van Buren | Cass | Allegan | Kalamazoo | **Total** |
|---|---|---|---|---|---|---|
| Total Acreage | 7,100 | 7,100 | 1,100 | 1,300 | 500 | 17,100 |
| Affected Acreage | 4,000 | 3,000 | 300 | 300 | 50 | 7,650 |
| **Acreage loss** | 950 | 450 | 75 | 50 | 25 | **1,550** |
| **Trees Lost** | 234,000 | 104,000 | 19,500 | 13,000 | 6,500 | **377,000** |
| *Assuming an average acre loss of 180 Bu/A ( 480 Bu/A Ave) | | | | | | |
| **Lost Crop Bu.*** | 1,278,000 | 1,278,000 | 198,000 | 234,000 | 90,000 | **3,078,000** |
| **Lost Crop $*** | $4,830,840 | $4,830,840 | $748,440 | $884,520 | $340,200 | **$11,634,840** |
| ** Assuming a loss of 50% (240 Bu/A) on affected acres and 100% (480 Bu) on lost acres | | | | | | |
| **Lost Crop Bu.**** | 1,188,000 | 828,000 | 90,000 | 84,000 | 18,000 | **2,208,000** |
| **Lost Crop $**** | $4,490,640 | $3,129,840 | $340,200 | $317,520 | $68,040 | **$8,346,240** |
| These loss figures are calculated using 1997 acreages | | | | | | |

## Total Loss Estimate

The total loss to the region includes the loss of crop in 2000 and lost yield from damaged or killed orchards which will take 4 to 5 years to recover to full yields. The total loss also includes the lost development cost of orchards where the majority of the trees were killed and the orchard was removed.

| Lost Income | |
|---|---|
| Crop Loss 2000 | $9,679,313 |
| Tree Loss 2000 | $9,305,338 |
| Crop Loss 2001 to 2005 | $23,230,350 |
| Total Loss | $42,215,002 |

## Advice for Growers

This epidemic will change the way we grow apples in Southwest Michigan. Most growers avoided fireblight susceptible varieties on dwarfing rootstocks, while other planted the new premium varieties hoping to maintain profits in a market with global oversupply, believing they could control fireblight. After this season, I doubt few growers will chance it again. Other growers planted those varieties on semi-dwarfing stocks and were still caught. Still others planted Golden Delicious hoping that fireblight would not be a serious problem. We had perfect conditions for fireblight during bloom followed by a severe storm which spread it throughout the area. We see it in nearly all apple blocks.

My advice to growers with severe fireblight at this time is to do nothing. Most of the damage for the year has already been done. There is no spray or cure for fireblight once it is in the trees. If there are only a few strikes in the orchard then pulling out shoots makes sense when symptoms first appear. But when there are many strikes in each tree then waiting until the disease stops spreading is a good option. Many Southwest growers have abandoned their crop in severely affected young orchards and sprayed with copper hoping to slow the spread of the disease. This is little more than a feel good option. It only reduces the population of bacteria on the trees. Copper has no effect on the bacteria in the trees. If your trees need calcium or potassium now is a time to apply it. Calcium helps maintain cell walls and membranes. Potassium is very important in water relations and may slow the advance of the disease in older tissues. I am not suggesting that you spray these materials on to trees. It would be more effective to determine what your orchard needs are and soil apply them at the usual time.

My recommendation is that fireblight affected branches be pruned out this winter. Several trips through the orchard should be made to be sure that all fireblight-affected branches are removed. Many growers in Southwest Michigan apply copper in the early spring. Next year I recommend we all do it.

Growers who do not use Maryblyt should get a copy and learn to use it. The 2000 fireblight season was stunning in the conditions during bloom were perfect for the rapid buildup of very high bacteria populations. When the danger of fireblight is extreme controls for blossom blight should be applied before infections if at all possible. For more information, see the Fireblight Articles at the University of West Virginia.

I have received numerous requests for use of High Quality pictures. I have created another file with more Pictures of Fireblight. This file contains high quality pictures from the 2000 epidemic and also pictures of different symptoms of fireblight on the shoots, spurs and fruit.

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# How Good Are Our Options With Copper, Bio-controls
# and Alliette for Fire Blight Control?

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(Presented at the Annual Meeting of the Va./W.Va. State Horticultural Societies, Roanoke, Va., January 13, 1998)

## Introduction

Fire blight is a greater problem today than in the past because our orchards and orchard management practices have changed considerably. There has been a shift toward the more lucrative fresh fruit market with many new varieties like Gala, Fuji, Braeburn, Gingergold, Jonagold which are very susceptible to fire blight. Orchards are also now planted at higher tree densities using 500 to 1,000 instead of 100 to 200 trees per acre. Such densities require smaller trees which is accomplished by using certain dwarfing rootstocks and tree training techniques that promote more bearing surface and less overall structure. The favored rootstocks are M-26 and M-9, both of which are very susceptible to fire blight and the tree training methods may contribute to the problem by reducing some of the inherent physiological resistance in apples to the progress of infections. In all, the risks for major limb and tree losses following even a modest outbreak of fire blight is much greater now than it was just 10 to 20 years ago.

With this increase in susceptibility to fire blight, the highly erratic nature of the disease and it destructive potential, it is often tempting to use existing materials for control more frequently than necessary Ajust for insurance@. This approach is especially dangerous now because we have only one effective antibiotic for preventing blossom infections -- streptomycin. Throughout the U.S., the emergence of streptomycin resistant strains in nearly all cases has been preceded by the excessive use of this antibiotic at six or more times per year on a routine basis. Fortunately, streptomycin has been traditionally used more conservatively in the mid-Atlantic region so we have yet to see significant problems with resistance. That situation, however, can change quickly in just a few years of excessive use when disease pressures are high.

In this situation we have two alternatives: [1] use streptomycin more efficiently, and [2] find alternative methods of control. Our best chances for stabilizing the risks for antibiotic resistance and for suppressing the damage caused by fire blight over the long term is to try to use both approaches wherever that can be done economically and effectively. Of the alternative methods currently available, three have received considerable attention in the research and trade literature: [1] use of copper containing materials; [2] use of Alliette or fosetyl-aluminum to trigger the apple tree=s natural defense mechanisms; and [3] use of bacterial bioantagonists for biological control. The purpose of this brief report is to review the current status of these options.

**Copper Materials for Fire Blight Control**

Copper sulfate was used in the mid-eighteenth century to control stinking smut of wheat. In the late nineteenth century, Millardet in the Bordeaux region of France found that a combination of copper sulfate and lime was effective against grape downy mildew. This so-called "Bordeaux mixture" has been used ever since in controlling a variety of fungus and bacterial diseases on many different crops. The effectiveness of copper against various pathogens is attributed to the availability of copper ions that inactivate many different enzymes and other proteins essential to vital cell membrane function. Unfortunately, this broad mode of action is not restricted to microorganisms but can also damage foliage and fruit on the crop plant. Indeed, on apples, this potential for phytotoxicity is the single most important factor limiting its effective use against fire blight beyond the green tip stage.

Alan Biggs (West Virginia University), Keith Yoder (Virginia Tech) and I have all looked at ways in which copper materials might be used safely after bloom to control, but we have all encountered problems with cumulative toxicity following multiple sprays and we still do not have reliable data on the efficacy of these materials used in this way. Thus, for now, we are limited to recommending copper treatments for use as a green tip spray. In making this treatment, however, it is important to first understand exactly what it is we wish to accomplish and how that might effect a developing epidemic. The primary purpose of this treatment is *not* to kill bacteria in the cankers or even to kill the bacteria as they ooze out of such sites. Indeed, even where copper residue covers the canker surface, the ooze is forced out in droplets or strands that "poke through" that residue exposing many live bacteria for dispersal in the orchard. The real role for copper in controlling fire blight is to provide an inhibitory barrier over all bark and bud surfaces in the orchard that will prevent the bacteria from colonizing these areas.

Keep in mind that, unlike apple scab, where spores are dispersed within hours of infection, the bacteria causing fire blight are dispersed, colonize and are redispersed repeatedly for several weeks before bloom when the first infections might occur. This, coupled with the fact that infections, when they occur, happen within minutes not hours, explains why incidents of fire blight often appear "explosive". Our recommendations for the use of copper materials at green tip, therefore, is to interfere with the widespread colonization of bark and bud surfaces throughout the orchard. For this to be effective, coverage must be thorough so a high volume spray is needed to completely wet all exposed surfaces in the orchard. In addition, since the dispersal and colonization of the bacteria is random and independent from the resistance or susceptibility of the trees, ***all of the trees in a treated block must be sprayed, not just those of susceptible varieties.*** Failure to also spray the normally fire blight resistant Red Delicious trees in an orchard interplanted with fire blight susceptible varieties provides a safe harbor for the bacteria to colonize and later be dispersed by honey bees to open flowers on all varieties, reducing if not totally negating the value of the treatment. Similarly, spraying only the fire blight susceptible crab apple pollinators in a Red Delicious orchard does not prevent the colonization of Red Delicious trees so that the stage is set for trauma blight damage to these if hail or high winds occur.

From a practical and economic standpoint, the copper material will serve effectively as the first scab spray of the season needed at green tip and it can also be tank mixed with 2 percent spray oil for mite and scale insect control at this time. The alkaline nature of most copper formulations, however, means that it cannot be used with most other insecticides and fungicides. For both efficacy and crop safety, the best timing for the copper treatment is after bud break at the green tip stage. Based on the modeling we=ve done in developing the *MARYBLYT*$^{TM}$ program, we think the greatest flux of bacteria onto bark surfaces occurs at about the tight cluster to pink stage. In some years this can be several weeks after a dormant application so that the copper residues we are counting on to prevent colonization can be greatly reduced through weathering. Work by Dave Rosenberger at Cornell warns against applications later than the half-inch green stage because these can produce unacceptable levels of fruit and foliar damage.

## Use of Alliette Fungicide for Fire Blight Control

Alliette, a new fungicide from Rhone-Poulanc, has shown efficacy in controlling collar rot, caused by the fungus *Phytophthora cactorum*. Alliette is also registered for use as a preventative against blossom blight, but the data supporting such a use is not at all convincing. The material has been tried for several years in Europe, the U.S. and Canada. Test results show that Alliette is never better than streptomycin, often affords significantly less control and, sometimes, appears to be ineffective. Alliette is reputed to trigger the production of inhibitory substances within the apple tree that provide some degree of natural resistance to fire blight. Whether this is the only mode of action or whether it applies equally well across all apple varieties is not known. Because of its systemic activity, it may ultimately prove to be more useful in reducing canker blight or rootstock blight, but to my knowledge no research is underway along these lines.

The bottom line on the use of Alliette for blossom blight is that its activity is too unreliable given the risks for severe crop and tree loss that are present even where the amount of fire blight may be modest.

## Use of Bioantagonists for Fire Blight Control

The use of biological control methods has always been an attractive goal for integrated crop management programs and, in some cases, they have proven to be very effective. However, it is important to understand the nature of biological control in that we are depending on a living organism to grow, multiply, and be dispersed as well and as rapidly, if not more so, than the pathogen or pest we hope to control. Just as the populations and dispersal of the fire blight bacterium vary with the weather, we can expect similar effects on most bioantagonistic microorganisms.

At present, there are two bacterial antagonists that have shown good activity in protecting against fire blight. One such material is marketed since 1995 as Blight Ban uses a strain of the bacterium, *Pseudomonas fluorescens*, Pf-A506. This agent multiplies rapidly and colonizes open flowers to the extent that it excludes any significant subsequent colonization by the fire blight organism. Tests in many locations, however, show that if this antagonist is applied after *Erwinia amylovora* is already present or even as a mixture with the pathogen, it is not effective. The second promising bioantagonist is another bacterium, *Erwinia herbicola,* strain C9-1, which is a common epiphyte on apples. In addition to the competition for space that occurs with Pf-A506, *E. herbicola* C9-1 also produces an antibiotic of its own that inhibits the multiplication of the pathogen. Like its A506 counterpart, this second bioantagonist must also be present in the flower before the arrival of the pathogen for it to be effective. This later strain, however, has not yet been approved by the EPA and so is not commercially available.

Both bioantagonists provide a moderate level of control against fire blight in most trials conducted across the U.S. There have been, however, a few unexplained failures which may have been due to other factors not under control of the researcher. Neither one nor both of these bioantagonists provide the overall control for blossom blight that is as dependable or as effective as streptomycin. Keep in mind, too, that while streptomycin appears to prevent or ameliorate some of the damage in trauma blight situations and is not effective against shoot blight, nothing is known about how these bioantagonists might affect phases of fire blight epidemics other than blossom blight. Since both strains are resistant to streptomycin (gene lies on the chromosome and not on a transmissible plasmid, so this type of resistance should be safe in that it is not likely to be transferred to pathogen strains), the best use of these bioantagonists at the beginning and at full bloom treatments along with streptomycin treatments scheduled in response to predicted infection events. At the present stage of development, these materials are probably a less attractive alternative to streptomycin in the mid-Atlantic region than in the western U.S. where it is reported that up to 85% of the pathogen isolates are already resistant to streptomycin.

On a more positive note, look for the development of other bioantagonistic strains of bacteria and, possibly, some yeasts as effective management tools for fire blight in the future. Early tests on some of these suggests greater activity and multiple modes of action that might work favorably in this region. Realistically, however, since apples is still considered a "minor" crop, one of the determining factors in how quickly and broadly new strains might be registered will be how well they act against other bacterial pathogens of other crops or have other complementary action such as frost protection.

### Preserving the Effectiveness of Streptomycin

Given the limitations of the above alternatives to streptomycin, we must pay special attention to effective resistance management tactics when using this valued antibiotic. In this regard:

**1.** Limit the use of streptomycin to bloom sprays needed to prevent blossom blight. Make these treatments only when needed using a forecasting program such as *MARYBLYT*™ to anticipate primary infection events. In this area this will mean zero to two applications in most years and, sometimes, three or four when bloom periods are extended.

**2.** Streptomycin is ineffective against canker blight and shoot blight and it should never be used in a protective program for this purpose.

**3.** Adopt an aggressive fire blight management program aimed at reducing the number and distribution of inoculum sources for all phases of the disease every year regardless of how much blight occurs and *never* apply streptomycin when symptoms of fire blight are present in the orchard.

**4.** The only exception to Rule 3 above is when streptomycin might be used immediately (within 12-18 hrs) following hail or high wind damage where there is a risk for trauma blight and treatments can be made within the allowable preharvest interval of 50 days on apples or 30 days for pears. Understand that this last approach is a "rescue mission" and that follow-up cutting as described earlier in this meeting will be needed.

### Summary

While there is a specific and justifiable role for copper materials in our current fire blight management program, copper treatments alone will not control this disease. Alliette is specifically not recommended at this time, because all test results thus far indicate that its effectiveness is too unreliable. The use of some Frost Ban (*Pseudomonas* A506) may provide some level of frost protection during the bloom period, but it should not be relied upon exclusively for fire blight control. Until we have more effective alternatives, we need to conserve the use of streptomycin by using it wisely as part of an overall aggressive fire blight management program.

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Fruit Disease Focus - March, 1998

# Fire Blight, *Erwinia amylovora*

by
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and
A. R. Biggs, West Virginia University

**I. Introduction:** Fire blight is a destructive bacterial disease of apples and pears that kills blossoms, shoots, limbs, and, sometimes, entire trees. The disease is generally common throughout the mid-Atlantic region although outbreaks are typically very erratic, causing severe losses in some orchards in some years and little or no significant damage in others. This erratic occurrence is attributed to differences in the availability of overwintering inoculum, the specific requirements governing infection, variations in specific local weather conditions, and the stage of development of the cultivars available. The destructive potential and sporadic nature of fire blight, along with the fact that epidemics often develop in several different phases, make this disease difficult and costly to control. Of the apple varieties planted in the mid-Atlantic region, those that are most susceptible include 'York', 'Rome', 'Jonathan', 'Jonagold', 'Idared', 'Tydeman's Red', 'Gala', 'Fuji', 'Braeburn', 'Lodi', and 'Liberty'. 'Stayman' and 'Golden Delicious' cultivars are moderately resistant and all strains of 'Delicious' are highly resistant to fire blight, except when tissues are damaged by frost, hail or high winds.

**II. Symptoms:** Overwintering cankers harboring the fire blight pathogen are often clearly visible on trunks and large limbs as slightly to deeply depressed areas of discolored bark, which are sometimes cracked about the margins. The largest number of cankers, however, are much smaller and not so easily distinguished. These occur on small limbs where blossom or shoot infections occurred the previous year and often around cuts made to remove blighted limbs. Since many of these cankers are established later in the season, they are not often strongly depressed and seldom show bark cracks at their margins. Also, they are often quite small, extending less than one inch (25 mm), with reddish to purple bark that may be covered with tiny black fungus fruiting bodies (most notably *Botryosphaeria obtusa*, the black rot pathogen of apple).

Blossom blight symptoms most often appear within one to two weeks after bloom and usually involve the entire blossom cluster, which wilts and dies, turning brown on apple (photo at left) and quite black on pear. When weather is favorable for pathogen development, globules of bacterial ooze can be seen on the blossoms (photo 2-20). The spur bearing the blossom cluster also dies and the infection may spread into and kill portions of the supporting limb. The tips of young infected shoots wilt, forming a very typical "shepherd's crook" symptom (photo 2-21). Older shoots that become infected after they develop about 20 leaves may not show this curling symptom at the tip. As the infection spreads down the shoot axis, the leaves first show dark streaks in the midveins, then wilt and turn brown, remaining tightly attached to the shoot throughout the season. As with blossom infections, the pathogen often invades and kills a portion of the limb supporting the infected shoot. The first symptom on water sprouts and shoots that are invaded systemically from nearby active cankers is the development of a yellow to orange discoloration of the shoot tip before wilting occurs (photo 2-22). In addition, the petioles and midveins of the basal leaves on such sprouts usually become necrotic before those at the shoot tip.

Depending on the cultivar and its stage of development at the time infection occurs, a single blossom or shoot infection can result in the death of an entire limb, and where the central leader or trunk of the tree is invaded, a major portion of the tree can be killed in just one season. In general, infections of any type that occur between petal fall and terminal bud set usually lead to the greatest limb and tree loss. In addition, heavily structured trees tend to suffer less severe limb loss than those trained to weaker systems for high productivity. Where highly susceptible apple rootstocks (M.26, M.9) become infected, much of the scion trunk and major limbs above the graft union very typically remain symptomless, while a distinct dark brown canker develops around the rootstock. As this rootstock canker girdles the tree, the upper portion shows symptoms of general decline (poor foliage color, weak growth) by mid to late season. In some instances, the foliage of trees affected by rootstock blight develop early fall red color in late August to early September, not unlike that often associated with collar rot disease caused by a soilborne fungus. Some trees with rootstock infections may not show decline symptoms until the following spring, at which time cankers can be seen extending upward into the lower trunk (photo 2-23).

**III. Disease Cycle:** The bacterial pathogen causing fire blight overwinters almost exclusively in cankers on limbs infected the previous season. The largest number of cankers and, hence, those most important in contributing inoculum, occur on limbs smaller than 1.5 inches (38 mm) in diameter, especially around cuts made the previous year to remove blighted limbs. During the early spring, in response to warmer temperatures and rapid bud development, the bacteria at canker margins begin multiplying rapidly and produce a thick yellowish to white ooze that is elaborated onto the bark surface up to several weeks before the bloom period. Many insect species (predominantly flies) are attracted to the ooze, and subsequently disperse the bacteria throughout the orchard. Once the first few open blossoms are colonized by the bacteria, pollinating insects rapidly move the pathogen to other flowers, initiating more blossom blight. These colonized flowers are subject to infection within minutes after any wetting event caused by rain or heavy dew when the average daily temperatures are equal to or greater than 60 F (16 C) while the flower petals are intact (flower receptacles and young fruits are resistant after petal fall). Once blossom infections occur, early symptoms can be expected with the accumulation of at least 103 degree days (DD) greater than 55 F (57 DD greater than 13 C) which, depending upon daily temperatures, may require 5 to 30 calendar days.

With the appearance of blossom blight symptoms, the number and distribution of inoculum sources in the orchard increase greatly. Inoculum from these sources is further spread by wind, rain, and many casual insect visitors to young shoot tips, increasing the likelihood for an outbreak of shoot blight. Recent research conducted in Pennsylvania indicates that aphid feeding does not contribute to shoot blight. More research is needed to determine whether or not leafhoppers play a role in the incidence of shoot blight. Most shoot tip infections occur between the time that the shoots have about nine to ten leaves and terminal bud set, when sources of inoculum and insect vectors are available, and daily temperatures average 60 F (16 C) or more.

In years when blossom infections do not occur, the primary sources of inoculum for the shoot blight phase are the overwintering cankers and, in particular, young water sprouts near these cankers, which become infected as the bacteria move into them systemically from the canker margins. Such systemic shoot infections, called canker blight, are apparently initiated about 200 DD greater than 55 F (111 DD greater than 13 C) after green tip, although visible symptoms may not be apparent until the accumulation of at least 300 DD greater than 55 F (167 DD greater than 13 C) after green tip. In the absence of blossom infections, the development of shoot blight infections is often localized around areas with overwintering cankers.

Although mature shoot and limb tissues are generally resistant to infection by E. amylovora, injuries caused by hail, late frosts of 28 F (-2 C) or lower, and high winds that damage the foliage can create a trauma blight situation in which the normal defense mechanisms in mature tissues are breached and infections occur. Instances of trauma blight are known to occur even on normally resistant cultivars like 'Delicious'.

Rootstock blight, yet another phase of fire blight, has been recognized recently and is associated primarily with the highly susceptible M.26 and M.9 rootstocks. On these trees, just a few blossom or shoot infections on the scion cultivar can supply bacteria that then move systemically into the rootstock where a canker often, but not always, develops and eventually girdles the tree. Trees affected by rootstock blight generally show symptoms of decline and early death by mid to late season, but may not be apparent until the following spring.

**IV. Monitoring:** Concentrate monitoring in orchard blocks where the disease occurred during the previous season. Observe blighted limbs and shoots for removal during normal pruning operation. There may be a need to remove whole trees on some occasions.

Where fire blight occurred the previous year in orchards grown on susceptible rootstocks (M.26, M.9), trees showing poor foliage color or dieback should be examined for rootstock cankers and, if found, removed from the orchard immediately and destroyed. A very important aspect of fire blight management involves monitoring the weather for the specific conditions that govern the build-up of inoculum in the orchard, the blossom infection process and the appearance of symptoms. A weather station (discussed in chapter 10) that records the daily minimum and maximum temperatures and rainfall amounts is needed. When 50 percent of the buds show green tissue, begin keeping a daily record of the cumulative degree days (DD) greater than 55 F (12.7 C; see Appendix B and F). This information can be used to signal when symptoms are likely to appear in the orchard for blossom blight [103 DD greater than 55 F (57 DD greater than 12.7 C) after infection] (photos 2-18, 2-20), canker blight [about 300 DD greater than 55 F (167 DD greater than 12.7 C) after green tip] (photo 2-22), and early shoot blight [about 103 DD greater than 55 F (57 DD greater than 12.7 C) after blossom blight or canker blight symptoms appear] (photo 2-21).

Continue to monitor and record the daily minimum and maximum temperatures and rainfall amounts, and continue to accumulate degree days (DD) greater than 55 F (12.7 C; see Appendix B and F). At the full pink stage (i.e., first flower open in the orchard), a record should also be kept of the cumulative degree hours (DH) greater than 65 F (18.3 C; see Appendix B and G). Once a total of 200 or more DH greater than 65 F (111 DH greater than 18.3 C) has accumulated after the start of bloom, any wetting event caused by rain or heavy dew that wets the foliage is likely to trigger a blossom infection event if the average daily temperature is 60 F (15.6 C) or more.

This information can be used to schedule streptomycin sprays, which are most effective if applied on the day before or the day of an infection event. Such sprays protect all flowers open at the time of treatment. However, because other flower buds may open after treatment, reassess the need for additional sprays at four-day intervals during bloom. Continue to monitor for strikes and remove all blighted limbs.

Monitor the orchard to locate blighted limbs (photo 2-22) for removal. For the greatest effect on the current season's damage severity, infected limbs should be removed as soon as early symptoms are detected and before extensive necrosis develops. Where the number and distribution of strikes is too great for removal within a few days, it may be best to leave most strikes and cut out only those that threaten the main stem. On young trees, and those on dwarfing rootstocks, early strikes in the tops of the trees often provide inoculum for later infections of shoots and sprouts on lower limbs near the trunk, which may result in tree loss. Give these early strikes a high priority for removal.

Look for symptoms of early tree decline or early fall color in orchards planted on highly susceptible rootstocks (M.26, M.9) where the disease developed this year. These symptoms may appear either on one side or throughout individual trees. Examine the rootstock area of these trees just below the graft union for evidence of cankering or bacterial ooze. Remove any tree showing these symptoms during this period.

**V. Management:** Many practices can help reduce the incidence of fire blight and may help reduce the severity of the disease when it occurs. Not all measures suggested below are necessary or even feasible in every planting, since planting systems play a large role in contributing to the level of risk of disease development. No single control method is adequate and, in regions where it is established, a conscious effort must be made to control the disease each year. Even under the most conscientious efforts, in some years losses from fire blight can be devastating.

**Chemical and biological control:** A copper spray applied at the 1/4-inch green tip stage may reduce the amount of inoculum on the outer surfaces of infected trees. At bloom, antibiotic sprays are highly effective against the blossom blight phase of the disease. These sprays are critical because effective early season disease control often prevents the disease from becoming established in an orchard. Predictive models, particularly Maryblyt, help to identify potential infection periods and improve the timing of antibiotic treatments, as well as avoid unnecessary treatments. Strains of the pathogen that are resistant to streptomycin are present in some orchards in the eastern U.S., and are widespread in most apple and pear regions of the western U.S. Biological control agents, although not widely used, have provided partial control of blossom infections. More effective biological agents are required if their use is to become widespread.

**Removing sources of infection:** Dormant pruning to remove overwintering infections helps reduce inoculum for the next season. Make cuts about 4 inches below any signs of dead bark. Remove pruned material from the orchard. Beginning about one week after petal fall, monitor the orchard to locate blighted limbs for removal. For the greatest effect on the current season's damage severity, infected limbs should be removed as soon as early symptoms are detected and before extensive necrosis develops. Where the number and distribution of strikes is too great for removal within a few days, it may be best to leave most strikes and cut out only those that threaten the main stem. On young trees, and those on dwarfing rootstocks, early strikes in the tops of the trees often provide inoculum for later infections of shoots and sprouts on lower limbs near the trunk, which may result in tree loss. Give these early strikes in the tops of trees a high priority for removal. Do not combine the practices of fire blight removal with pruning and training of young, high-density trees.

**Insect control:** The role of insects in the transmission of fire blight bacteria is under investigation. It is likely that insects that cause wounds (leafhoppers, plant bugs, pear psylla) can create places for bacteria to enter the tree, and some summer infections (shoot blight) are probably facilitated by insects. Where fire blight is a problem, and until more is known about their specific role in the spread of the disease, controlling these insects at levels below their economic injury threshold is advised.

**Cultural practices:** Use management systems that promote early cessation of tree growth without adversely affecting tree vigor. Excessive vigor is an important component of orchard risk for fire blight. When tree growth continues past mid summer, the likelihood that late season infections will overwinter increases. Orchards should be established on well-drained soils, avoiding low, frost-prone or potentially water-logged areas, and nitrogen fertilizer should be applied based on analyses of foliage N levels.

**Resistant cultivars:** When establishing new orchards, consider susceptibilities of the scion and rootstock to fire blight. Although none are immune, there is considerable variation among apple cultivars (and pear cultivars) in susceptibility to fire blight. Some cultivar/rootstock combinations are so susceptible to fire blight that investments in these are extremely high risk. In the eastern U.S., Gala on M.26 is a good example. Long range plans for establishing new orchards with fire blight susceptible cultivars should include contingency plans for controlling the disease without streptomycin.

**Additional Topics:**

Problems in Managing Fire Blight in High Density Orchards on M-9 and M-26 Rootstocks, Paul W. Steiner, Extension Fruit Pathologist, University of Maryland, College Park, MD
How Good are our Options with Copper, Bio-controls, and Aliette for Fire Blight Control?, Paul W. Steiner, Extension Fruit Pathologist, University of Maryland, College Park, MD
The Biology and Epidemiology of Fire Blight, Paul W. Steiner, Professor and Extension Fruit Pathologist, University of Maryland, College Park, MD (January 2000)
Managing Fire Blight in Apples, Paul W. Steiner, Professor and Extension Fruit Pathologist, University of Maryland, College Park, MD (January 2000)
A Philosophy for Effective Fire Blight Management, Paul W. Steiner, Professor and Extension Fruit Pathologist, University of Maryland, College Park, MD (January 2000)

**Chemical control - commercial growers**

**Chemical control - home orchardists (pdf file - Acrobat Reader required)**

# A Philosophy For Effective Fire Blight Management

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(Presented at the State Horticultural Association of Pennsylvania Annual Meeting, January 2000)

### Introduction

Success in plant disease management requires a change in philosophy about man's role in agriculture. Rachel Carson, in her revolutionary book, Silent Spring (1962), cited a most appropriate quote from E. B White: I am pessimistic about the human race because it is too ingenious for its own good. Our approach to nature is to beat it into submission. We would stand a better chance of survival if we accommodated ourselves to this planet and viewed it appreciatively instead of skeptically and dictatorially. Agroecosystems are not natural entities and exist only with the continued input of energy by man in his deliberate attempt to keep 'nature' in abeyance while he produces the food and fiber crops of his choice. Should that input be withdrawn, such systems are unstable and quickly begin to revert to the prevailing natural ecosystem.

The purpose of this discussion is to address the changes required in our thinking about disease management in the agroecosystem so that the strategies and tactics we choose to apply can be implemented with maximum effectiveness, a challenge that goes well beyond following standard 'control' recommendations.

### Problems posed by modern orchard agroecosystems

There are at least five major characteristics of modern agroecosystems aimed at economically efficient production that actually encourage the development of plant disease epidemics. All of these come into play when we look at the incidence and severity of fire blight under most conventional programs. If you doubt this, examine the changes in your own orchard operation over the last two decades and see how many of these factors seem to apply.

1. Limited number of plant species planted at high densities. Most modern apple orchards are limited to two species: apples and grass ground cover. Fifty years ago apple orchards were routinely planted at densities of 100 trees

per acre or less; now, we aim for tree populations of between 250 to 1,500 per acre.

2. Wide use of susceptible plants. While some apple cultivars demonstrate a moderate to high degree of resistance to fire blight, even that can be breeched by hail, wind or frost damage. Market demands over the last two decades have encouraged the production of new cultivars like Gala, Fuji, Braeburn, Empire, Ginger Gold and Granny Smith along with many traditional favorites like Rome, Jonathan, York and others that are moderately to highly susceptible to fire blight.

3. Wide use of genetically similar or identical cultivars and rootstocks. Apple and pear cultivars must be propagated vegetatively to maintain the characteristics of those varieties. In addition, to support the high tree densities that are now standard, clonal apple rootstocks such as M.26 and M.9 are widely used. Indeed, it is likely that 60% of U.S. apple production over the next decade will be on these two rootstocks which are both highly susceptible to fire blight.

4. Monoculture in time and space. Fruit crops are perennials and are planted with the full expectation that they will remain in place and productive for at least 15 to 20 years. This is monoculture in time. Monoculture in space occurs when a fruit industry develops in certain areas having climate and soil conditions most favorable for fruit production so that concentrations of several thousand acres or more provide an ideal base for maintaining important pathogen populations.

5. Uniform management practices throughout an orchard and across entire regions are required for both efficient production as well as for meeting specific market demands. As a result, large portions of the crop may be uniformly susceptible should conditions favorable for disease develop.

All of these factors are necessary for the efficient production of high quality apple and pear production. Eliminating even one of these factors reduces the viability of the business of commercial fruit production. Understanding the risks these elements pose for disease development, however, is an important step in the design and implementation of effective disease management programs that do not decrease the overall efficiency of production.

**Control vs. management philosophy**

The terms 'control' and 'management' are often used interchangeably when, in fact, they imply quite different approaches. In the early 1970s, J. Lawrence Apple summarized this issue nicely. Control, he suggests, implies a degree of dominance by man over nature that is simply not possible. Control also conveys a notion of finality, of having controlled and, thereby, dispatched a problem. Furthermore, should that problem develop again, the control action need only be repeated. Management, by contrast, implies an ongoing process that continues throughout a season and from season to season for the life of the crop. Management also implies that pathogens and pests are regular components of the agroecosystem and that our primary aim is to reduce the harm they cause rather than to annihilate them. Plant disease management, then, is the knowledgeable selection and use of all appropriate strategies and tactics to suppress the harm caused by disease to an acceptable level. When an explosive epidemic of fire blight occurs, it is hard to think of an "acceptable" threshold. At the same time, we have all experienced fire blight epidemics that are relatively minor affairs. One of the problems here is that when there is little fire blight in the orchard, little effort is expended in its management because the impact on total pack-out at the end of the season does not seem to justify the costs. In reality, the pay off with a continuing good management program for fire blight the overall effect is cumulative because the risks for damaging losses are not only reduced in the current season but in the seasons that follow.

**Epidemiological basis for disease management**

One of the unique characteristics of plant diseases is that they always develop as epidemics. The severity of these epidemics vary as a function of the amount of primary inoculum at the start of the each season and the apparent rate at which new infections occur. Every management tactic we might wish to use, whether cultural, biological or chemical accomplishes one or both of two primary objectives with respect to the development of epidemics: (1) reducing the amount of primary inoculum contributes to a delay in the development of an epidemic; and (2) reducing the apparent rates of infection slows the progress of the epidemic. The best plant disease management programs integrate the use of multiple tactics in a planned program to accomplish both of the above objectives. Tactics executed closest to the sources of inoculum are always more efficient in terms of overall input and those executed before infection are almost always more effective than those taken after infection. In our experience, even those methods taken after infection with the express purpose of reducing secondary sources of inoculum can have a major impact on reducing the overall losses commonly encountered with fire blight epidemics.

Deploying multiple strategies and tactics is the key to stabilizing a good disease management program because there is a multiplier effect, not an additive one. Using three different methods, each with the potential to reduce the amount and distribution of primary inoculum by 90% means a total reduction in the amount of inoculum to 0.1% [0.10 x 0.10 x 0.10 = 0.001 or 0.1%]. The addition of a similar combination of tactics aimed at reducing infection rates can have the end result of operating with inoculum levels of only 1/1000th the starting level with infections proceeding at 1/1000th the rate.

**Plant disease management and fire blight**

Our experience in using the Maryblyt© fire blight forecasting program and multiple approaches to eliminate sources of inoculum and reduce infection rates has proven that effective management can be accomplished using simple, conventional approaches that include one copper treatment, 3 or fewer streptomycin sprays and a pair of pruning shears. The key to this success lies in knowing when and how to use these simple tools for maximum effect. The best guide to the decision-making required for such this approach can be expressed in two sets of paired questions that need to be asked frequently throughout the life of the orchard: (1) Where is the pathogen now and what is it doing? and, (2) What am I doing and, specifically, why am I doing it? Let's examine each of the tactics routinely employed for fire blight management in the light of these two questions.

Dormant removal of all infected limbs is the first critical step. The purpose is to reduce the number and distribution of sources of primary inoculum that will fuel the following season's blight epidemic. During the winter, the pathogen is harbored in living bark tissues within an inch or less from the margins of overwintering cankers. This directed sanitation effort must be done every year in every orchard, regardless of how much blight developed the previous season.

Copper applications in the spring or fall have no effect on bacteria harbored internally in the bark tissues. These bacteria become active at approximately the tight cluster to early pink stage of apple bud development in response to the mobilization of reserve carbohydrates needed to support early bud and shoot development. A thorough application of copper (almost any formulation) not earlier than the green tip or later than half-inch green stage of bud development ensures the persistence of the greatest amount of active copper residue when it is needed to reduce the colonization of bark and bud surfaces that continues throughout the pre-bloom period. Such applications can be combined with spray oil for mite control and to enhance thorough coverage of copper and, indeed, will perform quite nicely as the first apple scab fungicide. Making this application earlier than green tip can subject copper residues to several weeks of weathering before they need to be in place. Furthermore, since the colonization of trees in the orchard is accomplished largely at random through wind, splashing rain and casual insect visits (mostly flies), maximum effectiveness can be achieved only when entire orchard blocks are treated, no just the trees most susceptible to fire blight. Applications after the half-inch stage carry a high risk for phytotoxic damage to foliage and fruit.

Streptomycin sprays during bloom are often, but not always, required to prevent blossom infections. Once the stigmas of the first open flower are colonized, further dispersal is no longer random but is directed specifically at other open flowers through the activities of honey bees and other pollinators. Even when thousands of flower stigmas are selectively colonized in this manner, infection does not occur until there is a continuous film of water is established between the stigmas and the nectarthodes in the base of the flowers, where 99% of blossom infections occur. There are four minimum requirements for the initiation of an epidemic of blossom blight: (1) the flowers must be open (to expose stigmas for colonization) with petals intact (flowers in petal fall are resistant); (2) the accumulation of 198 degree days >650F; (3) a wetting event occurring as either rain or dew; and (4) an average daily temperature of 600F or more.

When streptomycin is applied on the day of or the day before an anticipated blossom infection event, the level of control is nearly absolute. Applications made before or after this window are not totally ineffective, but can allow significant amounts of blossom blight to occur. Including an activator type spray adjuvant (e.g., Regulaid™) improves the coverage and penetration of streptomycin enough to allow reduced rates of this antibiotic to be used safely. Streptomycin does not kill bacteria but, instead, inhibits their multiplication and, thus, reduces the rate at which flower stigmas are colonized and, most importantly, the subsequent multiplication of the bacteria within the nectarthodes. Where coverage is good, any blossom open at the time of application is protected until its petals begin to fall and natural resistance comes into play. For this reason, streptomycin sprays should never be applied on an alternate row middle basis. Since 1988, when we first started making spray timing decisions using the Maryblyt© program, we've usually had cause to recommend only one or two sprays during bloom, sometimes none, occasionally three, and never four or more sprays. The conventional practice of using streptomycin at regular 4- to 5-day intervals during bloom, often provides adequate control but is usually excessive (more cost) and, sometimes, fails to prevent a serious outbreak.

Cutting out active infections is often viewed quite skeptically as being an impossible job that requires much labor and often seems to be ineffective. In truth, this practice can be extremely effective in limiting the number and distribution of secondary canker and shoot infections as well as reducing the risks for serious damage following summer hail and wind storms. To be really effective, cutting operations need to begin as soon as early symptoms appear. In addition, it is absolutely imperative that all cuts be made using the "ugly stub" approach in which cuts are always made into wood that is at least 2 years old to take advantage of natural physiological resistance expressed even in susceptible varieties. It has also been shown that there is no advantage to be gained by following the old recommendation of surface sterilizing cutting tools between each cut. The "ugly stub" method acknowledges the fact that the bacteria are systemic and can be several feet to yards ahead of any visible symptoms so that any cutting wounds provide an excellent opportunity for the resident bacteria to colonized and quickly establish a small canker around the cut. When cuts are made in the traditional fashion, flush with the next healthy branch union, many of these cankers will remain in the orchard to fuel next year's epidemic. Cutting back to a 4- to 6-inch naked stub does not prevent the formation of small cankers, but their position is now such that the stubs and the canker can be safely and completely removed during the regular dormant pruning operation. Simply spray painting these stubs makes them easier to find when the trees are dormant. The primary purpose of this cutting effort is to reduce the number and distribution of secondary sources of inoculum that can fuel a continuing epidemic of shoot blight through the season. Two factors are important in obtaining maximum effect: the cutting must begin promptly when early symptoms first appear; the cut material must be removed from the orchard; the cuts must be made following the ugly stub procedure; such cutting must be done every year, even when the overall amount of blight is very low.

A single streptomycin spray after hail or high wind damage is recommended as a prudent measure to limit the ability of the bacteria to colonize the many open wounds in the orchards. Such treatments, however, must be made within 12 to 18 hours after the damage.

**An optimistic prognosis**

The repeated use of all these multiple measures every year, regardless of the amount of blight that might develop greatly reduces the risks for catastrophic losses due to fire blight even in seasons when conditions favoring disease development occur. Single method or "silver bullet" approaches will never be effective in managing a disease like fire blight. Silver bullets are known to be effective in only one instance - in dispatching werewolves. We have much more to learn about fire blight management, but I'm confident that this approach program will allow us to not only continue the use of the highly susceptible M.26 and M.9 clonal apple rootstocks, but to begin looking at redeveloping a viable commercial pear industry in the Eastern U.S. The potential for new products like Actigard™ [Novartis, Inc.] to induce systemic acquired resistance and Apogee™ [BASF, Inc.] to curtail limit the development of secondary shoot infections can only enhance the effectiveness of this management approach in dealing with destructive fire blight.

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# Managing Fire Blight in Apples

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**INTRODUCTION**

Fire blight of apples and pears has been known in North America for over 200 years, but its control has never been quite mastered to the degree possible with many other plant diseases. Epidemics can develop rapidly in orchards with no history of the disease, destroying much of the current crop and killing many large limbs or whole trees in a short time. They can also be fairly minor affairs, causing no significant economic damage, even in orchards with severe blight the previous season. Between these extremes, variation in the incidence and severity of fire blight that seems to follow no particular pattern from season to season and orchard to orchard is characteristic.

Given the sporadic nature of fire blight, it is not surprising that some of our management tactics sometimes fail to provide consistent control. There are instances, for example, where considerable blossom blight occurs despite a grower's best efforts to follow a recommended program of orchard sanitation and protective antibiotic sprays during bloom. In other seasons, a similar spray program seem excessive given the small amount of disease that occurs in nearby untreated orchards. Finally, even when no blossom blight occurs, damaging epidemics of shoot blight can develop and hail storms can trigger severe outbreaks.

Managing fire blight well is also difficult because our tactical options are limited largely to cutting out infected limbs and applying copper-containing formulations or antibiotics. Unfortunately, copper materials are often phytotoxic, antibiotics are really only effective against blossom infections, and cutting can be inefficient when the amount of disease is high. Excessive antibiotic use has also led to the emergence of resistant strains of the pathogen in some areas. Changes in modern orchard management practice and market demand over the last two decades have increased the vulnerability of many orchards. For example, instead of planting 100 to 200 apple trees per acre, orchards are now planted at up to10 times that density. Such high densities require the use of size-controlling rootstocks, of which the two most widely used, M.26 and M.9, are highly susceptible to fire blight.

Adding to the risk of loss is an increase in the acreage planted to new fresh market apple varieties like Gala, Fuji, Braeburn, and Granny Smith along with older favorites like Rome, Ida Red, and Jonathan, all of which are very susceptible. Finally, to maximize production efficiency in these high density orchards, strong vegetative tree growth is encouraged in young orchards so that trees fill their allotted space within 3 years. Various methods of tree training are then used to induce flowering at the expense of vegetative growth so that infections often lead to more limb and tree death than generally experienced with larger trees.

The purpose of this discussion to outline an effective approach to fire blight management that is not only reliable for the current season, but reduces the risks of severe losses in subsequent seasons, even when conditions for infection are favorable. The program is one that I have developed over the last decade in conjunction with the Maryblyt™ program for forecasting fire blight infection events and symptom development. While good execution of this management plan is aided by the use of the Maryblyt™ program, it is not required. What is required, however, is a change in your philosophy about disease control and disease management.

**CONTROL vs. MANAGEMENT**

One of the first things to understand about agriculture is that it is not natural. Agroecosystems, whether they involve annual or perennial crops, exist only with the continued input of energy by man. Should that input be withdrawn, the system quickly reverts to the prevailing natural ecosystem for the region. Thus, man's aim in agriculture has really evolved into an approach designed to keep nature in abeyance. Such domination of nature is tenuous at best. Plant disease 'control' and 'management' are two terms often used interchangeably, despite the fact that they encompass very different approaches. Control implies a degree of finality of having controlled and, thereby, dispatched the problem through some specific action by the grower. Along this same line, it is often assumed that if a disease has been 'controlled', its reoccurrence at a damaging level then the tactics failed or that control can be reclaimed by simply repeating the treatment. Management, by contrast, implies a continuing process that addresses all phases of a disease and the crop rather than some single tactic. Management also implies that pathogens are a part of the natural ecosystem and that our primary goal is to reduce the harm caused by disease, not just to kill pathogens. In this sense, a management approach seeks to find ways in which man can establish and maintain his crops in a manner that is least disruptive to natural conditions. This requires continuous adjustments to meet conditions such as crop maturity and weather as they change over the course of a season as well as from season to season.

Plant disease management decisions are based on epidemiological principles aimed at disrupting the development of damaging epidemics rather that trying to prevent all disease. This is accomplished by reducing the number and distribution of inoculum sources and reducing the apparent rates at which new infections occur. The most stable disease management programs utilize both of these approaches, often using a variety of strategies and tactics. Plant disease management, therefore, is the knowledgeable selection and use of all appropriate strategies and tactics to suppress the harm caused by diseases to a level that is economically acceptable. This is a tall order for fire blight epidemics which have a high potential to develop explosively, reaching levels that seem beyond the limits of management.

**FIRE BLIGHT MANAGEMENT**

The essence of a good fire blight management program has three aims: (1) reducing the number and distribution of both primary and secondary inoculum before that inoculum can be widely dispersed; (2) preventing blossom infections; and, (3) reducing the rate at which infections progress. Removing sources of primary inoculum and reducing the efficacy of any remaining inoculum are generally the most efficient tactics in a disease management program while those employed to prevent infection are nearly always more effective than those taken after infection.

### *3.1 Reducing Primary Inoculum*

Dormant pruning. E. amylovora overwinters only in living tissues at the margins of indeterminate bark cankers so thorough pruning during the dormant season to remove diseased limbs is an absolute necessity. This effort will also remove much of the primary inoculum of the black rot, white rot and bitter rot fungus pathogens that commonly colonize dead wood in trees.

Copper sprays. Copper is an effective bactericide and almost any copper material is effective [Bordeaux mix, Kocide, Copper Count-N, etc.]. The purpose of this treatment is not to kill bacteria within cankers, but to reduce the efficacy of the bacteria in colonizing bark and bud surfaces during the early, pre-bloom period. For this reason, spray coverage needs to be very thorough and is best achieved using 0.2 to 0.4 gallons of dilute spray mixture per 1,000 ft3 of tree row volume or at least 100 to 200 gallons per acre.

Since the bacteria generally become available in the orchard when infectious activity at canker margins begins at the tight cluster to early pink stage of bud development [estimated at 93 cumulative degree days (CDD) >550F after green tip], applying copper materials before green tip only subjects the residues to weathering before they need to be available. A second critical caution is that copper needs to be applied to entire orchard blocks, not just to rows of susceptible varieties. This is important because inoculum dispersal by flies and other insects during the pre-bloom period is largely a random process occurring throughout the orchard without regard to cultivar susceptibility. Spraying only the susceptible trees in an orchard allows the bacteria to colonize bark surfaces on untreated trees and, subsequently, to be splashed or moved to open blossoms where pollinating insects can easily move the inoculum to flowers on susceptible trees, completely bypassing any copper residues.

Orchard monitoring. Because many overwintering cankers are small or can be overlooked during the winter pruning effort, a follow-up monitoring effort is needed to locate and remove any remaining active canker sites. Here, the regular appearance of early canker blight symptoms with the accumulation of about 300 DD >550F after green tip is an opportunity not to be missed. This effort probably has the greatest impact in years when blossom blight does not occur or is well controlled. Where the dormant sanitation effort is thorough, the number of active canker sites remaining is likely to be small, but, when blossom blight is not a factor, these few sites are the only source of inoculum within an orchard to fuel an epidemic of shoot blight or to set the stage for a trauma blight situation.

*3.2 Preventing Blossom Infections*

The prevention of blossom infections has always been and will always be a major emphasis in any fire blight management program. In the past, even the most conservative approaches such as the routine application of 3 to 4 streptomycin antibiotic sprays during the bloom period sometimes failed for unexplained reasons. Now, with the Maryblyt™ program, infection events can be predicted accurately and far enough in advance to allow antibiotic treatments to be made on the day before or the day of an anticipated event so that the level of control is improved and, very often, while using only 1 or 2 and sometimes no sprays in a season. If streptomycin cannot be applied before infection, it can still provide up to 90 percent control if applied 24 to 48 hours after infection which, depending upon the number of blossoms present can still mean a considerable loss and many sources of inoculum for secondary infections.

Blight Ban™, a biological control formulation using the bacterium, Pseudomonas fluorescens A-506, which aggressively competes for space on flower stigmas with the pathogen, E. amylovora is also registered for use on apples and pears. To be effective, however, Blight Ban™ needs to be applied 1 or 2 times each season, regardless of whether infection events occur. This biocontrol organism is not effective if it arrives on stigma surfaces at the same time or after the pathogen gets there. Tests using this material in the Mid-Atlantic area have not provided consistent control when compared with streptomycin programs. Another chemical option which is not yet registered for use is Actigard™ (Novartis). This material works very differently than other materials in that it induces the host tree's normal resistance mechanisms to become operable early and shows some promise for fire blight blossom blight control, especially where streptomycin resistance may be a problem. Like biocontrol agents, however, Actigard™ will also need to be applied each season regardless of any immediate risk of infection because it needs about 5 to 7days lead time.

*3.3 Reducing shoot blight*

As methods for blossom blight control have improved, research on the nature and control of shoot blight has become more focused. Despite the long-held implication of sucking insects in outbreaks of shoot blight, there is little proof that such a relationship exists. Research in Pennsylvania has specifically excluded green apple aphids while work in Virginia and Utah fairly well excludes white apple leafhoppers. In Virginia, there is some evidence that potato leafhoppers may play a role, but it is doubtful that this one species explains the worldwide incidence and continuing occurrence of shoot tip infections over several months during the season. At the same time, there is mounting evidence that gusty winds may cause small injuries to tender shoot tips through which bacteria on their surfaces may then enter and initiate infections.

From a timely control program, this presents two problems. First, streptomycin has proven to be ineffective in preventing shoot tip infections and most copper formulations have the potential for phytotoxicity. Secondly, even if a good bactericide becomes available, it hardly seems practical to try spraying whole orchards every time the wind blows with gusts more than 8 to 10 mph between petal fall and terminal bud set. The most practical approach, therefore, is still to reduce the ;number and distribution of secondary sources of inoculum by aggressively cutting out new infections early to reduce supply the bacteria which colonize growing shoot tips.

One of the most promising developments for shoot blight control is a gibberellic acid synthesis inhibitor called Apogee™ (prohexadione-calcium, BASF) which appears to be on a 'fast track' for registration either this year or next. Excellent results in limiting shoot blight has been developed in Michigan (Al Jones, Michigan State Univ.) and Virginia (Keith Yoder, Virginia Tech) on the use of this material in one or two applications beginning at petal fall. There are few 'magic silver bullets' in plant disease management, however, so that even if Apogee™ does become available soon, it will still be important to continue all basic efforts to reduce the number and distribution of inoculum sources as outlined above.

*3.4 Reducing Secondary Inoculum*

As fire blight epidemics get underway, the number of secondary infections increases rapidly because each infection site supplies additional inoculum for dispersal throughout orchards by wind, water and insects. Even where blossom blight does not occur or is well controlled, vegetative shoot infections can still cause much damage to the tree including a loss of total bearing surface. Cutting out or breaking off infected shoots has been tried often, but its effectiveness has always been questioned because some years it seems to work and some years it seems to fail miserably. There is also the preconceived notion that when cutting has to be done the amount of cutting required is neither practical or economical because of the time and labor required. In truth, cutting out active infections can be extremely effective if done at the right time and in the right way.

Cutting out active infections. To be effective in slowing the current season's epidemic, cutting must begin as soon as early symptoms appear. The late Ron Covey in Washington state demonstrated that delaying the first of several cutting efforts by two weeks resulted in the removal of six times more wood than where cutting was begun immediately. 'Early', in this sense, means as soon as wilt symptoms are apparent and before significant necrosis develops. One reason for this is that even before shoot tips wilt, droplets of bacterial ooze are often present on otherwise symptomless shoots and these are sources of inoculum for further dispersal. One advantage of the Maryblyt™ program is that it has proven to be quite accurate (+ 0-2 days) in predicting the early appearance of blossom, canker, shoot and trauma blight symptoms so that orchard monitoring and cutting operations can be anticipated.

How the cuts are made is also important and has a substantial amount to do with how much carryover inoculum will be available the following year. Conventional recommendations often suggest that cuts be made 8 to 12 inches below the leading edge of symptoms and that cutting tools be surface sterilized with copper materials or alcohol between each cut. We've found the bacterial pathogen as far as 9 feet back on a branch with a single terminal shoot tip infection. This is far beyond the limit where most growers want to or is necessary to cut. In addition, because the bacteria are already internal in the infected limb, the sterilization of tools between cuts is of little practical value.

When infected shoots and branches are removed, living cells are cut and bruised, allowing their contents to be readily available for immediate colonization by the bacteria already present in xylem tissues so that small cankers (1/4-inch or less) forms around many cuts regardless of whether tools are sterilized. As this infection progresses into healthy wood where reserve carbohydrate levels exceed those of the bacterial ooze, water is denied the bacteria and canker extension stops. If cuts are made back to the next healthy branch union following conventional practice, this small canker will remain in the orchard and provide primary inoculum for next year's epidemic.

Through a process I call "ugly stub" cutting, cuts are still made 8 to 12 inches below visible symptoms, but always into 2-year or older wood (high carbohydrates) and then leaving a 4- to 5-inch naked stub above the next leaf, spur or branch. Although small cankers will still form around a significant number of these cuts, the ugly stubs can be easily recognized during the dormant pruning operation and removed at that time. A number of growers adopting this practice on a regular basis routinely spray paint the ugly stub bright orange so that they can be more easily located during the winter. This procedure is an important step in that it removes sources of inoculum in the orchard quickly which reduces the rate at which secondary infections occur and it has longer term effects in that fewer cankers are left in the orchard to fuel next year's epidemic. It also has the very practical advantage of being much faster in that the tedious job of sterilizing tools between cuts is not necessary so long as the only consideration at the time is the removal of infected shoots. This last caution is important because such cutting forays should never be combined with routine summer pruning efforts.

### *3.5 Rootstock blight*

As noted previously, rootstock cankers that kill whole trees is a problem largely experienced with the M.26 and M.9 apple rootstocks and C-6 inter-stems. We have also seen it develop on M.7 and M.111 rootstocks although, here, the rootstock cankers are not as aggressive as on M.26 and M.9 and rarely kill trees. The bacteria move quickly from scion infection sites down through the xylem elements in other otherwise healthy limbs and trunks and into the rootstock in most trees, even though only about 5 to 10 percent of trees with scion infections succumb to rootstock blight each year during the first 5-6 years after planting.

In Maryland, we have noted the odd situation in that rootstock cankers are not generally initiated where the bacteria first contacts the rootstock at the graft union but only at 4 to 6 inches below ground, regardless of how high the graft is located above ground. Research is continuing in Maryland to discover what event(s) might initiate the development of rootstock cankers. There are, of course, new fire blight resistant rootstocks under development which might replace M.26 and M.9, but these are still many years away from thorough field testing in growers' orchards.

**SUMMARY**

Managing fire blight well in high density apple orchards of highly susceptible varieties on highly susceptible rootstocks is entirely possible. It requires, however, an aggressive approach using a variety of well-timed and well-executed tactics that continually aim at reducing the number and distribution of inoculum sources throughout the orchard throughout the season every year, regardless of how much fire blight occurs. Indeed, the greatest impact on limiting the damage caused by fire blight is possible in those years when little blight occurs. Our experience with growers following the management approach outlined here is that within three years, they reach a point where they no longer have a high risk for catastrophic loss, even when conditions for severe blight (multiple blossom infection events and hail storms) occur.

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# Problems in Managing Fire Blight in High Density
# Orchards on M-9 and M-26 Rootstocks

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### Introduction

Fire blight has been known in North America for over 200 years and throughout much of that history, its management has been difficult because we lacked essential details about the nature of the infection process. This knowledge gap is becoming even more critical now since changes in orchard management practices implemented over the last two decades have increased our vulnerability to devastating blight epidemics. Four factors contribute to this increased risk. First, instead of planting 100 to 200 trees per acre, we now routinely set between 500 and 1,000 trees per acre. Second, the only way to accomplish such high tree densities is to use size controlling rootstocks like M-9 and M-26 which are both widely used and very susceptible to fire blight. Third, fresh fruit market demands have encouraged widespread plantings of many new varieties such as Gala, Fuji, Braeburn, Granny Smith, Empire, Gingergold, and Jonagold which, along with older favorites like Rome, Ida Red and Jonathan are all very susceptible to fire blight. Finally, in adopting the tree training systems needed to make high density plantings more productive, the trees are pushed into bearing early and deliberately maintained with a minimum of vegetative structure so that some natural physiological mechanisms that resist the progress of infections may be reduced. The purpose of this report is to summarize developments over the last 10 years which have the potential to reduce the risks for damage in today's orchards.

### What is rootstock blight?

What makes fire blight a truly significant problem in high density orchards planted on either the M-26 or M-9 rootstock is a phenomena called "rootstock blight". While the blighting of these rootstocks has been observed for many years, it was thought that the primary avenue for infections by the bacterium, *Erwinia amylovora*, was fairly direct through root suckers, cracks in the bark or insect injuries below the graft union. Based on numerous observations over the last 10 years and research conducted at the University of Maryland in the early 1990s, we know now that the primary route of entry for the bacteria into the rootstock is internally, through otherwise healthy limbs and trunks from even a few blossom or shoot strikes on the scion variety. Once the bacteria reach a susceptible rootstock, they initiate the formation of new cankers that can completely girdle and kill the tree in one to a few months.

We have seen rootstock blight in the field and reproduced it in the greenhouse on other rootstocks such as M-7A and M-111, but the rootstock cankers that develop are never as aggressive as they are on M-26 and M-9 and rarely kill trees. We still lack key information on the physiological and environmental factors that determine if and when rootstock cankers develop, because not all trees showing scion infections later succumb to rootstock blight. Nevertheless, our observations in Maryland and those of researchers in New York estimate that an average of between 5 and 15 percent of the trees in an orchard showing symptoms of scion infection (blossom, shoot or trauma blight) die each year once trees begin flowering. Keep in mind that this is an *average* loss, and that losses as high as 60 to 80 percent of the trees in a young orchard over a two year period have been observed more than once in several locations.

In this region, the gross symptoms of rootstock blight occur in four phases: 1) oozing of bacterial masses from the rootstock within 2 to 4 weeks after symptoms appear on the scion variety; 2) rapid death of the entire tree in late June to late July; 3) the development of early fall red color in late August to early September on the leaves of trees that are partially girdled but will die before winter; and, 4) early decline and death of the tree in the spring following infection, often showing the active development of a bark canker extending upwards into the scion trunk from the rootstock. Be aware, too, that where hail or high winds contribute to a trauma blight event, tree losses due to rootstock infections with M-26 and M-9 also can occur on normally resistant Delicious trees even though the scion strikes may not run very far.

In the future we hope to have a number of fire blight resistant rootstocks capable of producing a tree with all of the characteristics needed for high density orchards. Until these can be fully tested and made available, however, we have no direct methods for controlling the rootstock phase of infections. Our only alternative is to change the way in which we approach fire blight management using existing tactics; this is entirely possible.

**Managing Fire Blight**

As our approach to growing apples has changed, so too must our philosophy about pest and disease management. Before looking at the specifics of an aggressive blight management program it may be useful to first look at what is meant by plant disease management. *Plant disease management is the knowledgeable selection and use of all appropriate technologies to suppress the damage caused by diseases below an acceptable economic threshold.* The words "management" and "control" are often used interchangeably when, indeed, they often imply different ideas that can influence how well a disease management program works. Some 20 years ago, J. Lawrence Apple summarized these differences. The word "control", for example, implies a degree of dominance by man that is simply impossible. It also implies a degree of finality of having controlled and, thereby, dispatched the problem through some specific action on the part of the grower. "Management", by contrast, implies a continuing effort or process addressing all phases of the disease and the crop rather than the application of some specific extrinsic factor. Management also implies that our primary goal is to reduce the harm caused by disease, not to kill pathogens. As semantic as it might seem, the significance of this difference in approach is clear when we look at the success we've had in dealing with fire blight.

As a perspective on why I recommend this approach, keep in mind just a few of the reasons why fire blight is such a formidable foe.

- Unlike apple scab where primary inoculum is dispersed just prior to infection, fire blight bacteria are dispersed widely for several weeks to a month or longer before actual inoculation and the first infections occur.
- The fire blight pathogen, *Erwinia amylovora*, is a competent epiphyte capable of colonizing and multiplying on the surfaces of plants. Furthermore, it makes little difference whether the plants colonized are susceptible or resistant to fire blight.
- At moderately warm temperatures in the 65-75$^{o}$F range, the bacterium has the potential to double every 20-30 minutes. One bacterium gives rise to 1 trillion cells with just 31 divisions which occur within just 2-3 days.
- Because blossom infections occur within minutes, even a single wetting event under the right conditions at bloom can increase the number of inoculum sources in an orchard from a few overwintering cankers to several hundred thousand blighted spurs very quickly. Indeed, when conditions are favorable, just spraying water at bloom can incite 100s of blossom infections per tree.
- Each new infection provides trillions of new bacteria available for dispersal by wind, water and insects contributing to secondary infection cycles and additional losses that often develop exponentially over time.
- Where hail or high winds strike a otherwise healthy orchard that has been colonized by the bacteria, fire blight infections can be initiated on nearly every tree, even on Delicious trees that generally exhibit strong resistance.
- In orchards where fire blight has occurred previously, primary inoculum arises from overwintering cankers, many of which are small and difficult to find\remove. This inoculum along with any subsequent inoculum contributed from infected blossoms fuels a continuing epidemic of shoot blight and can set the stage for the infection of mature tissues in a trauma blight situation.

The only way to manage fire blight under the high risk conditions present in our modern high density orchards planted to susceptible varieties on highly susceptible rootstocks is by implementing an aggressive fire blight management program. The program outlined here focuses on reducing the number and distribution of inoculum sources within an orchard on a continuing basis throughout the year, every year, regardless of how much blight occurs.

Without question and before any other steps are taken, it is mandatory that all visibly infected spurs, shoots and limbs be removed during the dormant pruning period. A complete coverage copper spray is recommended at green tip and should be applied using a total spray volume that ensures thorough wetting of all bark and bud surfaces on ALL trees in a given orchard block, not just on susceptible varieties. The purpose of this treatment is to reduce the efficacy of primary inoculum in colonizing these surfaces during the prebloom period. Copper is NOT effective in killing the bacteria harbored within cankers or in preventing that inoculum from being extruded onto the bark surface.

Streptomycin antibiotic is the only material available that has the potential to fully protect the highly susceptible apple and pear flowers, but for maximum effect it must be applied the day of or the day before an infection event occurs. The *MARYBLYT* forecasting program works very well in the mid-Atlantic region for identifying periods of high risk for infections and in identifying specific infection events when they occur. Missing that critical window of effectiveness by even 24 hours can result in only 80-90% control and those infections that do arise can provide significant amounts of inoculum for later infections and a continuing epidemic

The *MARYBLYT* program can also help in timing orchard monitoring efforts to locate new infections because it accurately predicts what kind of symptoms are likely to be found and when. Here, symptoms of both blossom blight and canker blight are important. In years when blossom blight is well controlled or when no blossom infection events occur, the importance of locating and thoroughly removing all sources of canker blight early cannot be under stated. Even a few active cankers in an orchard can supply the initial inoculum needed to place the whole orchard at risk from the ravages of shoot and trauma blight.

Keep in mind that, because of the inoculum potential and the ability of new inoculum to be repeatedly dispersed throughout an orchard by wind, splashing rain and insects, ***there is no such thing as a "little bit" of fire blight!!*** An aggressive fire blight management program requires that all infections, regardless of their apparent insignificance in location on a tree or time of year, be removed quickly as soon as symptoms develop. Note that I say "as soon as symptoms develop" and not "as soon as you find it" or "as soon as the number of new strikes seems to slow down". This is because the advantage of reducing inoculum potential and having an effect on this year's epidemic passes quickly. The late removal of blighted shoots and limbs is, in effect, little more than revenge because the bacteria they release have already be redispersed many times in the orchard.

As a general rule, I suggest that if you can remove all of the blight showing within two days after it begins to appear, do it. If it will require much longer, it may be best to let nature take its course and concentrate your efforts on cutting for salvage where infections threaten to enter the main tree stem or occur in the tops of trees. The cutting effort also goes much faster if additional time for tool sterilization between cuts is not needed. In our work, we have found the bacteria in the internal bark tissues of limbs 3 to 9 feet ahead of any visible symptom. Note, too, that even where pruning tools and the bark surfaces where cuts are to be made are *both* thoroughly sterilized, small cankers still develop around the cutting wound in a large number of cases. Where removal cuts are made in the traditional fashion of pruning back to the next healthy branch union, many small cankers will be missed during the dormant pruning effort and will provide inoculum for the next year=s epidemic.

All cutting to remove fire blight should be done following the "ugly stub" procedure. Here, blighted shoots and limbs are cut 8 to 12 inches or more below any visible symptoms (same as in traditional recommendations), but leaving a naked stub in wood that is at least 2 years old and approximately 4 to 5 inches short of the next branch union or spur. The inevitable cankers that will form on many of these cuts are then in a position so that they can be easily removed during the dormant period when it is too cold for the bacteria to produce a new canker. Finding such "ugly stubs" in the winter is made easier if, at the time of cutting, the stubs are spray painted with bright orange paint. This two-step cutting procedure is designed to eliminate cankers from the orchard and, thus, reducing the inoculum potential and the risks for early orchard colonization in the following season. Remember that, in years when fire blight is not severe and only a few trees are involved, you can afford to be more severe in your cutting operations. This means that whole limbs or trees can be removed without having a significant effect on the current season's crop while having a major impact on how much inoculum might be available in subsequent seasons.

**The Payoff with Good Management**

Fire blight is a "new world" disease. The bacterium, *Erwinia amylovora*, was already in North America when the first colonists arrived and probably caused infections on native species of crab apple, hawthorn and mountain ash. Since the late 1950s, fire blight has marched through all of Europe, the Middle East and into Asia. None of the often drastic measures tried by more than one government to eradicate the pathogen from early sites of infection have been successful. Since the introduction of *MARYBLYT* and emphasis on the adoption of an aggressive fire blight management program in Maryland over the last 10 years, we have observed not only an overall improvement in the level of control, but a reduction in the amount of spraying required and, most significantly, the ability to withstand severe hail events with only minor secondary losses due to fire blight where, previously, such incidents would have resulted in serious tree losses.

**TI: Fate of Escherichia coli O157:H7 on fresh-cut apple tissue and its potential for transmission by fruit flies.**
AU: Janisiewicz-WJ; Conway-WS; Brown-MW; Sapers-GM; Fratamico-P; Buchanan-RL
SO: Applied-and-Environmental-Microbiology. 1999, 65: 1, 1-5; 28 ref.
LA: English
AB: A study was carried out to determine the population dynamics of E. coli on wounded apple tissues, apple juice and apple cider. Pathogenic E. coli O157:H7, as well as non-pathogenic strains ATCC 11775 and ATCC 23716, grew exponentially in wounds on Golden Delicious apple fruit. The exponential growth occurred over a longer time period on fruit inoculated with a lower concentration of the bacterium than on fruit inoculated with a higher concentration. The bacterium reached the maximum population supported in the wounds regardless of the initial inoculum concentrations. Populations of E. coli O157:H7 in various concentrations of sterilized apple juice and unsterilized cider declined over time and declined more quickly in diluted juice and cider. The decline was greater in the unsterilized cider than in juice, which may have resulted from the interaction of E. coli O157:H7 with natural populations of yeasts that increased with time. Experiments on the transmission of E. coli by fruit flies, collected from a compost pile of decaying apples and peaches, were conducted with strain F-11775, a fluorescent transformant of the non-pathogenic E. coli ATCC 11775. Fruit flies were easily contaminated externally and internally with E. coli F-11775 after contact with the bacterium source. The flies transmitted this bacterium to uncontaminated apple wounds, resulting in a high incidence of contaminated wounds. Populations of the bacterium in apple wounds increased significantly during the first 48 h after transmission.
PT: Journal-article
AN: 19991005448

Record 21 of 42 in CAB Abstracts 2002/08-2003/04

**TI: Internalization of Escherichia coli in apples under natural conditions.**
AU: Seeman-BK; Sumner-SS; Marini-R; Kniel-KE
SO: Dairy,-Food-and-Environmental-Sanitation. 2002, 22: 9, 667-673; 20 ref.
LA: English
AB: Foodborne illnesses caused by drinking unpasteurized apple cider have been attributed to the pathogenic bacterium Escherichia coli O157:H7. Contamination is likely to occur during the fruit growing and harvesting phases. In apple cider production in which the entire apple is pressed, pathogens found within the apple core and surrounding tissue are a potential problem. Internalization of E. coli in apples under natural environmental conditions was addressed in this study by use of a controlled outdoor setting. A surrogate E. coli species (ATCC 25922) was used as an alternative to the pathogenic species. The bacterial culture was applied to topsoil and spread evenly on a 6 x 6-foot area. Red Delicious, Golden Delicious, and Rome Beauty apples were placed randomly on the soil, much like drop or windfall apples. The position of each apple was noted as to whether it had fallen calyx up, calyx down or on its side. Apples were examined for the presence of E. coli and sampled on days 1, 3, 8, and 10. Skin, flesh, inner core, and outer core samples were plated on MacConkey agar supplemented with cycloheximide and MUG for ease of identification. Escherichia coli was found in the inner core

and flesh samples of all apple varieties, indicating the potential for infiltration by the organism outside of laboratory conditions.
PT: Journal-article
AN: 20023155149