Fire Blight of Apple and Pear in Canada: Economic Importance and a Strategy for Sustainable Management of the Disease

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Introduction

Fire blight, caused by the bacterium *Erwinia amylovora*, is a devastating disease of apples and pears, as well as other species in the *Rosaceae* family. The economic importance of fire blight is not always easy to appreciate, as it is an erratic disease, but severe outbreaks can result in millions of dollars of production and tree losses. The severity and huge economic impact of these outbreaks are due to *E. amylovora* bacteria's ability to rapidly move internally in host plant tissues. Although the bacterium can enter through wounds and natural openings, it preferentially enters through open blossoms. Flower infections lead to a loss of the current season's crop, but on sensitive cultivars, when climactic conditions are favourable, the bacterium moves rapidly from the flower to the pedicel and then to twigs and branches, and may progress down the trunk. This migration results in the loss of whole branches and trees and severely infected orchards, if they survive, may never live up to their economic potential. The plates on pages 21 and 22 provide visual identification of fire blight symptoms in apple and pear.

The disease has been indicated as a major reason for the limited acreage of pears grown in eastern North America. In Canada, pears are mainly grown in Ontario (1054 ha) and British Columbia (344 ha), with smaller acreages in Nova Scotia and Québec (Statistics Canada, 2003). In total approximately 13,000 metric tonnes are produced (fresh and processing) at a farm gate value of $10,000,000 (2003 figures, Statistics Canada).

In the last 10 to 15 years the importance of this disease, and the potential for economic losses, has increased dramatically in Canadian apple production as well. Due to an increasingly competitive global market, Canadian apple growers have had to shift their operations to newer cultivars and high-density apple plantings, which bring trees into production sooner and produce a higher percentage of high quality fruit. Many of the new cultivars, which are bringing the highest returns to growers, are also highly susceptible to fire blight (e.g. Gala, Fuji, Gingergold, Honeycrisp, Braeburn). The dwarfing rootstocks used in high-density orchards (e.g. M.9, Ott.3 and M.26) are all very susceptible to fire blight. The management techniques for high-density plantings also lend themselves to greater risks of fire blight infection (smaller trees, more bearing surface, more risk of fire blight infecting rootstocks, higher risk of bacteria moving from tree to tree, etc.). Additionally, changing weather patterns (generally warmer, wetter springs, particularly in eastern Canada) have favoured more frequent outbreaks of the disease in commercial apple and pear orchards. Finally, because nursery trees, for planting in orchards, are often sourced from the U.S. (e.g. from Washington, Oregon, and Michigan) there is a risk that trees carrying antibiotic-resistant bacteria end up in Canadian orchards, making control of fire blight more difficult with existing chemical tools.

Economic Impact of Fire Blight to Apple and Pear Production.

The National Center for Food and Agricultural Policy in the U.S. reported on annual estimated losses of apple in the U.S. (Gianessi *et al*. 2002): With about 50% of apple cultivars grown in the U.S. being highly susceptible to fire blight, annual losses to the disease are estimated at 5% of the total production or 100 million kg, valued at US$35.6 million annually. If these figures were extrapolated to Canadian apple production, which is about 1/10th the size of the U.S.', annual losses to fire blight would be in the range of $4 million.

As an example of the severe economic impact that fire blight can have, one has just to look at the outbreak of the disease that occurred in Washington State in 1998, which affected 36,000 acres of apples and 10,000 acres of pears. WSU extentionist, Dr.Tim Smith, estimated an industry cost of $68,000,000 for Washington and Oregon combined in that year. A major epidemic in Southwest Michigan in 2000 destroyed over 250,000 apple trees and more than 1,000 acres of apples were lost. The establishment cost of these orchards was over US$9 million. Apple yields were reduced by 35% over the region, with some growers suffering 100% losses in some plantings. The Southwest region of MI produces an average of 4.5 to 7 million bushels and the crop loss in 2000 was 2.7 million bushels, worth about US$10 million. It will take at least 5 years for yields to recover with a cumulative loss of yield of nearly US$36 million. The region's total economic loss was estimated at almost US$42 million (Longstroth 2001).

In Canada the provinces do not maintain any quantitative records of losses to fire blight. Crop insurance agency figures highly underestimate tree losses as only a small fraction of pear and apple growers purchase the optional tree rider. However, interviews with provincial government extension staff, consultants, and growers provided qualitative figures and estimates, which are provided below:

Southern Ontario (south of an imaginary line from Sarnia to Toronto) has the highest annual risk of severe fire blight outbreaks, due to its moderate climate, frequent spring precipitation and warmer temperatures during bloom. For example, favourable weather conditions during bloom led to severe outbreaks of fire blight in 1991 and resulted in apple and pear growers removing whole blocks of orchard that were considered unsalvageable (estimated at several hundred acres in total) and diligent follow-up management was required in less severely affected blocks for several years to follow (re-pruning out infected wood and treating with streptomycin). In 1992 a severe windstorm and resulting injury to apple leaves from blowing sand, resulted in the removal of approximately 25 acres of Idared, Cortland, and Mutsu, as well as a small block of pears, from a Norfolk County orchard. Several hundred additional acres were severely affected by shoot blight infections (Solymár, pers. observ.). Hail also accounts for major losses to fire blight (trauma blight symptoms) in some years. There are examples of orchards that have received hail in 6 out of the last 8 years. In 2002-2003, a 25-acre planting of young Gala and Gingergold trees on M.9 rootstock were removed in Essex County due to fire blight moving into the trunks and rootstocks and killing the trees. Best estimates are that thousands of apple and pear trees representing several hundred acres have been removed due to fire blight over the last decade in Ontario (Solymár, pers. observ.).

Québec and cooler parts of Ontario (e.g. Grey county and Eastern Ontario) have had outbreaks of fire blight as well, some resulting in removal of blocks of newer plantings. Based on comments from Vincent Phillion, pathologist with MAPAQ, an outbreak in an orchard in Rougemont in 2002 resulted in the loss of 5000 trees on dwarfing rootstock (4^{th} to 6^{th} leaf) and the mandatory removal of an additional 5000 bearing trees. Approximately 30 growers in the vicinity of that orchard spent an estimated 300 hours each in pruning out infected wood. Cost of the above was estimated at over $800,000. Insurance claims from area growers for reduced production after the 2003 season resulted in payouts of $1.2 million. Ironically, the reduction in crop came not from fire blight but from growers not using pollination services, due to fear of spread of the bacteria by honeybees.

Gordon Braun, research pathologist with AAFC in Kentville, NS provides the following summary of fire blight incidence in Nova Scotia: “Fire blight is present in Nova Scotia each year but only in a few orchards. In most years blossom blight is not a significant problem and the majority of the fire blight in apple and pear is shoot blight starting from over-wintered cankers systemically infecting shoots. There is some infection of late blossoms and the remainder is insect transmitted. Of the three growers I know who have had a perennial problem with fire blight, pruning is their primary control strategy. One grower has used Streptomycin treatments and pruning, and the removal of very susceptible varieties to virtually eradicate fire blight from his apple orchard”. Bill Craig, AgraPoint International Inc., comments that he recalls only one major incidence of fire blight in his 25 years as an extension specialist in the Annapolis Valley. However, with the increasing acreage being planted to Honeycrisp in that province and warmer summers the risk of fire blight may become more serious in that province.
Gayle Jesperson, BCMAFF, comments that the disease occurs sporadically in BC, with a small number of growers affected every year, some of these severely impacted. There have been situations where whole blocks of pears or newer apple cultivars were removed due to the severity of the outbreak. Although BC tends to have less of a problem with blossom blight infections, due to their relatively cool, dry springs, the actual economic risk of a fire blight outbreak are greatly magnified for two reasons: 1) due to soaring land costs growers are planting at densities of up to 1700 trees/acre and higher (huge initial investments in trees, support systems and irrigation), and 2) documented resistance to streptomycin. The high tree densities mean increased risk of rootstock blight, more rapid spread of the disease, and potential for enormous financial setbacks. The presence of streptomycin-resistant fire blight pathogen in an orchard, in the absence of other chemical controls, could be devastating in a year when blossom time conditions are conducive to the disease.

An epidemic outbreak of fire blight in a given geographic area has the potential to destroy the economic viability of apple and pear production in that agricultural production region. An example is the processing pear industry in Ontario. That province has the largest acreage of pears and most of that acreage is in the Niagara Peninsula where hot, humid conditions are very conducive to fire blight infections. The Ontario farm value for pears is $4 million for fresh market production and $2.5 million for processing. A reduction in the yield of Ontario’s processing pear crop (primarily cv. Bartlett), due to a fire blight epidemic, could also, indirectly, put the canning peach industry at risk (net farm gate value of Ontario processed peaches was $3.9 M in 2000). There is a strong interdependence between these industries as Kraft (located in St.

Davids) is the key processor of peaches and pears. Reductions in the supply of Ontario pears may eventually lead to an economic decision by the processor to re-locate south of the border. This would have a devastating impact on pear and peach growers in Niagara and surrounding areas.

A fire blight epidemic also has the potential of substantially increasing a grower's labour costs. Labour already is the single largest expense to an orchard operation – averaging at about 35% to 40% of total expenses. An infection requires diligent and regular (often weekly) pruning trips through the orchard. Pruners must be disinfected after each cut and all cut out wood removed from the orchard and destroyed. In a 40 acre orchard this can add thousand's of dollars to labour costs.

The Canadian apple industry has a farm gate value of $175,420,000 (5-year average, 1998-2002, Statistics Canada). There are over 20,000 bearing hectares of apple orchards and an additional 4,000 hectares of non-bearing orchard planted (2002 figures). The large majority of apple cultivars and rootstocks being planted today are either susceptible or highly susceptible to fire blight. Using production figures, it is estimated that 89% of all apple and pears produced in Canada come from fire blight-susceptible cultivars (see Table 1). Especially in Ontario and British Columbia, where about 50% of apples and pears are highly susceptible, and the risk of a fire blight epidemic is highest due to warmer climates, the impact of a severe outbreak (particularly without adequate protection with streptomycin applications) would be devastating. In Ontario about 40% of apple rootstocks and 90% of pear rootstocks planted are susceptible to fire blight. In British Columbia, closer to 90% of rootstocks are susceptible to the disease.

Table 1. Fire Blight Susceptibility of Apples and Pears Grown in Canada ('000 metric tonnes)[1]

Cultivar Susceptibility	**BC**	**ON**	**QE**	**NB**	**NS**	**Total**
Low	21.5	27.2	1.9	-	1.9	52.5 (11%)
Moderate	54.3	118.4	83.2	4.3	27.5	287.7 (63%)
High	44.3	53.5	9.6	-	9.4	116.8 (26%)

[1] Two-year average based on 2003 figures and 2004 preliminary figures. All provinces include processing apples and pears in cultivar estimates. All pears are assumed to be highly susceptible to fire blight.
Re. "other" and "early" apple cultivars - assumptions of "high" fire blight susceptibility were made for 75% of BC, 50% of ON and 25% of other provinces
Source: Provincial apple producer organizations, BC Tree Fruit and OMAF

Appendix I outlines three different scenarios of potential economic losses due to fire blight outbreaks. Although the scenarios are based on a number of assumptions and may use dated cost of production values, the magnitude of losses, due to fire blight, are nevertheless impressive. From these examples it becomes very clear that a significant fire blight outbreak, and the inability to access efficacious control tools, may result in a grower, or even a local industry, never being able to recover from that outbreak.
Due to its sporadic nature it can be difficult to quantify the true risk that this bacterial disease poses to Canadian apple and pear production. Of one thing there is no doubt: the

risks for potential crop loss, tree loss and economic setbacks are very serious in a year when climactic conditions favour the disease.

Registered Products for Management of Fire Blight in Canada and in the U.S.

In Canada, several copper formulations are registered (see Table 2) and act by reducing *E. amylovora* inoculum by providing an inhibitory barrier over bark and bud surfaces, thereby preventing the bacteria from colonizing these areas. Because copper is toxic to plant tissue (e.g. cause fruit russeting), the product is usually applied as a Bordeaux mixture, a mixture of copper and hydrated lime (as a safener), after green tissue is present. Most formulations are registered for bloom applications, only a "fixed copper" formulation is registered for use at silver tip/delayed dormant. Depending on formulation, 2 to 4 kg/ha are recommended in sufficient water for thorough coverage. Most labels recommend up to 2 applications per season. Cost in 2004 was between $10-13 per kg.

Table 2. Registered products for fire blight control/suppression in Canada

Material/ Manufacturer	Recommended Rate and Timing	Comments
streptomycin (Streptomycin 17) UAP Canada Inc.	600g/1000L water. Begin sprays at 20-30% bloom and repeat at 14-day intervals, up to 3 sprays.	No longer registered for trauma blight events (e.g. hail storm)
Fixed copper UAP Canada Inc.	4 kg/ha Make 2 applications – one at silvertip & one after harvest (50% leaf drop)	Apple only.
Copper sulphate (Triangle brand) Phelps Dodge Refining Corp.	Use as Bordeaux mixture 2-6-1000 in 3000L/ha water. Apply when 50% blossoms open.	For apples and pears.
Copper from tri-basic copper sulphate (Copper 53W) UAP Canada Inc.	Use as Bordeaux mixture 1-6-1000 in 3000L/ha water. Apply when 50% blossoms open.	For apple and pear. Also registered for blister spot on apple.
copper oxychloride (Guardsman brand) Univar Canada Inc.	2.25 kg/ha Apply when blossoms open, repeat immediately if hail occurs.	Registered for use on pear in BC only.

Streptomycin, an antibiotic, is the only product registered as a control for fire blight in Canada. It selectively inhibits the growth of *E. amylovora*, when applied directly to the surface of the plant. It is most effective when applied for blossom blight control during warm (over 18^{o}C) temperatures with extended drying periods on the plant surface. Streptomycin breaks down very quickly in sunlight and must, therefore, be reapplied every 2-3 days if conditions continue to be conducive to fire blight infections.

Dr. Antonet Svircev and colleagues at Agriculture and Agri-Food Canada conducted a streptomycin residue study in Ontario in 2002 (Smith *et al*. 2002). Samples were collected from 5 orchards (1 in Essex, 1 in Norfolk and 3 in Niagara) a data collected on dislodgeable foliar residue (DFR). Sampling took place 1,2, 7, 14 and 30 days post-application. After 30 days there was no detectable residue on 3 of the 5 samples, and the

remaining 2 had significant decreases in DFR (one had no detectable residue after 7 days but a second application of Streptomycin was made 7 days after the first due to continuing high risk of infection by fire blight.
In Canada streptomycin has a 50-day pre-harvest interval on apple, and 30 days on pear. The label allows for a maximum of 3 applications (600 gm in 1000L of water), with a maximum of 5.4 kg/ha/year, up to 14 days after petal fall. The retail cost for streptomycin in 2004 was $120/kg.

For several years, annual 1-year registration extensions for streptomycin were granted. Currently the product is registered to December 2006. The label use of streptomycin for trauma blight (e.g. damaging hailstorms) control was removed from the label by the Pest Management Regulatory Agency (PMRA) in 2001.

Apogee™, or prohexadione Ca, received registration in April 2005, but only enough material to cover 3000 acres will be available for sale in Canada in the first year. Apogee™ is a growth regulator that inhibits gibberellin biosynthesis thereby stunting actively growing shoots. It helps reduce shoot blight symptoms of fire blight by reducing terminal shoot growth and inducing earlier “hardening”. An additional advantage is that the “hardened” shoots are less attractive to insect vectors like leafhoppers, aphids and mirids. Apogee™ needs to be considered a “suppressive” product, for use following blossom sprays of Streptomycin. Its usefulness in vulnerable non-bearing plantings, where the emphasis is on encouraging shoot growth to allow a tree to “fill its space” (and hence fruit bearing surface) as quickly as possible, is questionable. It is not effective in controlling blossom, trauma or rootstock blight.

As a comparison to Canada, Table 3 outlines the products currently registered for control/suppression for fire blight in the United States.

Worldwide, streptomycin and other antibiotics remain the most efficacious materials for control of fire blight. Several other products, including bacterial antagonists (e.g. *Pantoea agglomerans* C9-1, *Pseudomonas fluorescens* A506, and *Bacillus subtillus*), systemic acquired resistance (SAR) inducers (e.g. harpin protein, or Messenger™), gibberellin inhibitors (e.g. prohexadione calcium, or Apogee™), and other products are also registered. However, all comparisons of these products to antibiotics indicate that they only suppress *E. amylovora* but do not control the disease (see Appendix II). As a result, in countries where antibiotics are registered, these materials are recommended for use in an integrated program with streptomycin (or other antibiotics).

Table 3. Registered products for fire blight control/suppression in the United States

Material/ Manufacturer	**Recommended Rate and Timing**	**Comments**
streptomycin (Streptomycin 17) FarmSaver.com	24-48 oz./acre At 20-30% bloom, repeat every 3-4 days. After petal fall every 10-14 days for twig blight	
oxytetracycline (Mycoshield) Nufarm Agriculture Division	1 lb/100 gal Begin applications at 10% bloom and repeat at 4-6 day intervals	On pears, and Section 18 on apple (annual renewal in WA, OR, MI. Phytotoxicity may occur in sevsitive pear cultivars (e.g. Asian pears).
copper hydroxide (Champ) Nufarm Agriculture Division	5.5-10.5 pints/acre Between silver tip and green tip.	
copper hydroxide (Kocide) Griffin	2-4 lbs/acre Between silver tip and green tip. ¼ lb at 20% bloom and again at 75% bloom.	
Copper oxychloride + basic copper sulphate (C-O-C-S) UAP	2-4 lbs/acre Between silver tip and green tip.	
aluminum-tris (Aliette) Bayer	2.25-5.0 lbs/100 gal Begin applications when adequate foliage available, reapply every 4-7 days.	"…used in a program with other registered bactericides and recommended sanitation measures aids in the control of fire blight…"
Pseudomonas fluorescens A506 (BlightBan A506) Nufarm Agriculture Division	200gm. Beginning early bloom, with 1 to 2 more applications	"Blightban should be used in an integrated fire blight suppression program. Blightban improves suppression with an existing antibiotic spray program" Registered also for frost protection on numerous crops
Bacillus subtillus (Serenade) AgraQuest, Inc.	2-4 lbs./acre Begin 1-5% bloom, repeat 3-7 day intervals	"For suppression". "Do not tankmix with pesticides, adjuvants, surfactants, or fertilizers"
Harpin protein (Messenger) Eden BioScience	6.67-13.35 oz/acre 2 pre-bloom sprays (green tip onwards) and post-bloom sprays at 14-day intervals.	"Messenger is recommended to boost overall vigour and production of apple and to aid in management of apple scab and fire blight" Note: Research at Cornell University indicates that results are extremely variable and this product is not considered effective.
prohexadione calcium (Apogee) BASF	Various rates depending on growth stage of tree. Apply at 1'-3' shoot growth and repeat.	Apogee is a plant growth regulator. "…will reduce incidence and severity of fire blight infection of shoots and leaves…..can decease host susceptibility.

A Sustainable Fire Blight Management Strategy for the Canadian Apple and Pear Industries

To manage a disease such as fire blight an integrated strategy must be employed. Relying on any one technique or chemical product is not viable. An understanding of the disease and it's biology, the ability to utilize predictive modelling tools to determine periods of high risk of infection (especially during bloom), the careful management of factors that may contribute to outbreaks of fire blight (e.g. nutrition program, pruning methods, irrigation timing and type), aggressive pruning and removal of "strikes" and the diligent use of chemical compounds (e.g., copper and streptomycin) all contribute to an integrated management strategy for this disease. Appendix III outlines recommended procedures to manage fire blight in apple and pear orchards based on a phenological time line.

There are always improvements that can be made to any pest management strategy and apple and pear growers will readily adopt these if they are shown to be effective in preventing economic losses. At the same time, the apple and pear industry relies on research, technology transfer and regulatory bodies to help implement new pest management techniques. The following are key considerations for apple and pear growers to be able to adopt more sustainable fire blight management strategies:

Research Strategies

There are only 3 researchers in Canada, all with Agriculture and Agri-Food Canada, who currently conduct fire blight research. Their activities are summarized below:

Dr. Antonet Svircev, Vineland, ON - fire blight control with elicitor proteins, transgenics and elicitor proteins, control of the fire blight pathogen with bacteriophages

Dr. David Hunter, Vineland, ON – breeding resistance to fire blight in pear cultivars

Dr. Peter Sholberg, Summerland, BC – efficacy testing of new products, co-operation with research projects headed by Dr. Svircev.

The Canadian apple and pear industry feels strongly that current levels of funding for primary, applied research (A-base funding) being conducted by the researchers described above must be maintained and enhanced. Fire blight, as the most economically significant disease of apple and pear, should be a number one priority for AAFC. Without a strong commitment to continued research into managing this important problem the entire apple and pear industry in this country is put at increased risk of financial devastation. A long-term commitment to maintain existing programs and person-years is urgently needed, as well as additional research commitments into the following areas:

- Testing of new technologies for fire blight management, including bacterial antagonists, SAR inducers, blossom thinners (caustic sprays), sea buckthorn sprays, copper-manzate spray mixtures, and other potential tools.

- Evaluation of SAR inducers and foliar nutrients in increasing tree health and immunity.
- Developing mechanisms of bacterial antagonist dispersal using honeybees.
- Evaluation using repeated low-rate copper applications after a crop is lost to fire blight to minimize further spread and infections by the bacteria.
- Increased cooperation with Cornell University and University of Guelph to field test in Canada, respectively, the Cornell-Geneva and Vineland rootstock series for resistance to fire blight, and potential commercial production.
- Maintain close working relationship with Cornell University's transgenics program. Attain permission/cooperation to field test material in Canada.

The Canadian apple and pear industry understands that important long-term research is also being conducted elsewhere in the world. Resources in Canada must be appropriately allocated to meet the short-term needs (e.g. testing of new fire blight management tools, resistance management strategies, etc.) and the long-term needs of the industry. Obviously it would not be practical or fiscally responsible for Agriculture and Agri-Food Canada to initiate expensive and long-term breeding programs (beyond those that exist) or development of transgenic cultivar lines with resistance to fire blight. However, what the industry does want is for AAFC researchers and provincial governments to closely network and interact with scientists at Cornell University, the USDA in Kearneysville, Michigan State University, Washington State University and research programs in countries like New Zealand, Germany and France. All efforts should be made to pursue partnership opportunities where new fire blight-resistant cultivars and rootstocks are concurrently tested in Canada.

The science of developing genetically modified apple and pear trees (scion or rootstock) is both a long-term strategy and controversial. Although a significant transgenic breeding program is on-going at Cornell University in New York, the release of any commercialized plant material is still several decades away. Market acceptance of genetically-modified organisms is an on-going public issue. Resistance to the science of transgenics by the public and consumer groups may mean that GMO apples will never be planted. Additionally, in British Columbia, where there is a growing organic industry (particularly in the south Okanagan) there will be strong resistance and lobbying from that sector against transgenic apples or pears.

<u>Technology Transfer/Grower Education</u>

Until the early and mid- 1990s, provincial government agriculture ministries delivered grower extension activities. Tree fruit and IPM extension staff provided one-on-one consultation to apple and pear growers, organized orchard tours and "twilight" meetings, developed extension publications and pest management spray guidelines, and offered regional "agriphone" or "code-a-phone" services, which provided regular updates on pest population activity through the growing season. These extension experts also became familiarized with, and then introduced growers to Maryblyt, as a fire blight prediction tool.

Over the last decade provincial governments have gradually downsized their extension staff and traditional technology transfer programs have disappeared. In their place various new delivery mechanisms have been developed, sometimes via partnerships between government and industry, other times solely by industry. For example, in Nova Scotia the government eliminated their extension service but now provide the industry with funding for a “privatized” consulting service, AgraPoint International. In Québec “Clubs d’Encadrement Technique” (CET) comprised of 15 to 40 growers in a geographic area, are serviced by crop/IPM consultants, whose salaries are subsidized by the provincial government. In Ontario several independent IPM consultants and packing house staff organize IPM monitoring programs in various apple growing areas of the province, but no government assistance currently exists). In British Columbia packinghouse field staff and private consultants provide monitoring and IPM services.

Today, delivery of integrated fire blight management strategies should be a cooperative effort between researchers, provincial governments, industry and private IPM practitioners, with the first two primarily responsible for development of new strategies and the latter two for delivery of those strategies to growers. Long-term commitments by provincial governments are required to continue to provide technology transfer of new and innovative fire blight management strategies to the grower.

Key technology transfer concepts are:

Fire blight prediction models –

Fire blight prediction tools are a critical component of an integrated fire blight management program to assess risk of infections, especially during bloom, so as to best time streptomycin sprays. Alternately, when the models predict low risk unnecessary applications of streptomycin can be avoided.

Maryblyt has traditionally been the predictive model used in Ontario and other eastern provinces. British Columbia has been using Cougarblight, perhaps because it was developed at Washington, an area similar to BC growing conditions. The former is copyrighted, available only in DOS and was sold by Gemplers, an agricultural supply company. However, a recent check indicates that Maryblyt is no longer commercially available. Currently a Windows version is under development by Gary Lightner at USDA Kearneysville, and further refinements are being incorporated at Cornell University (Aldwinkle, pers. comm.). When the new product will be available in the market is presently unknown.

Cougarblight, developed at Washington State University, on the other hand, is available free of charge on the Web and a Celsius version has also been developed. Several years of comparison of the MaryBlyt and Cougarblight by Aldwinkle and Breth in New York led them to the conclusion that, although there are slight differences between the predictive powers of the two models, either is acceptable.

Rootstock Recommendations –

IPM practitioners should be actively recommending the use of fire blight “resistant” rootstocks, especially in the geographic areas in the country where fire blight outbreak occurrences are most frequent and most severe. This requires encouraging apple and pear growers to plan well in advance for new plantings and re-plant situations so as to include custom ordering of trees grown on these rootstocks. IPM practitioners should also facilitate enhanced communications between growers and nurserymen. This will increase understanding of grower needs and nursery production time lines.

Apple and pear growers plant the cultivars that are in demand by the marketplace and that offer the highest returns. Often these are those that are the most susceptible to fire blight. However, rootstock choices are more flexible and there are several options available. For pear growers the Old Home x Farmingdale (OH x F) series of rootstocks exhibit higher resistance to fire blight than Bartlett or Quince rootstock. For apple growers, B.9, a dwarfing rootstock, as well as the Cornell-Geneva (C-G) and Vineland series’ provide enhanced resistance to fire blight. Regrettably, commercial availability of these is limited. The C-G and Vineland rootstocks are just now being tested and only limited test quantities are available. The OH x F pear rootstocks are commercially available, but generally cost more as they are more difficult to propagate and must be custom ordered. The B.9 apple rootstock is perhaps the most widely available and several growers in the more fire blight prone areas in southwestern Ontario area now exclusively re-planting with this rootstock specifically to reduce losses to fire blight.

Testing of newly registered products –

Most materials being developed and registered worldwide to manage fire blight are “suppression tools” that compliment the use of streptomycin. Chemistries such as biological antagonists (e.g. BlightBan and Serenade), gibberellin inhibitors (e.g. Apogee) and SAR inducers (e.g. Messenger) must be applied at very specific phenological stages in order to realize optimal benefits. This requires a learning curve for apple and pear growers that can be facilitated by IPM practitioners. As these new materials receive registration in Canada, practitioners should be working with industry to ensure growers become comfortable in the application timing and techniques, and their fit in an integrated strategy. This can be accomplished initially through workshops and IPM schools, followed by on-farm demonstration trials and one-on-one consultations with growers. An outline of the process of registration and industry adoption is outlined in Appendix II.

On-farm demonstrations –
There is an old saying that goes, “I hear and I forget, I see and I remember, I do and I understand”. There is no substitution for the transfer of information to an agricultural industry like a well-designed field demonstration trial. The strategy is to enlist several innovative and well-respected growers, who are willing to test new techniques and strategies on their farms. A well-developed experimental design ensures adequate replication, randomization and scrutiny of collected data using statistical processes. A

series of grower tours to the site and well-constructed annual reports of findings allows exposure to a wider grower audience. Examples of techniques that might be demonstrated are aggressive winter pruning to remove fire blight strikes, pruning using the “ugly stub” method during the growing season, comparisons of Apogee-treated versus non-treated rows or blocks of various cultivars, use of hail netting on young high-density plantings to reduce trauma blight incidence, and testing of new reduced risk insecticides for insect vectors, such as leafhoppers and stinging bugs.

Extension articles and publications-

Due to human nature and the sporadic nature of fire blight, apple and pear growers may become complacent and relax their vigilance in managing fire blight over several “low risk” years where weather during bloom is not conducive to the disease. The regular and frequent exposure to written material can help keep growers prepared for inevitable high incidence years. Whether presented in industry media, newsletters, meeting presentations, workshops or other educational media, frequent exposure to the economic dangers of the disease keeps growers informed and up-to-date. Emphasis should be placed on an integrated approach to fire blight management including the use of predictive risk models.

Extension activities for nursery operators –

Extension activities for fruit tree and ornamental nurseries on diagnosing and preventing fire blight are needed. Development of a best management practices extension publication and instructional video on care of nursery and non-bearing orchard plantings would be a valuable addition to current literature on fire blight.
The need for increased propagation of fire blight resistant rootstock must be conveyed to tree fruit nursery operators, and government extension could work with nurserymen in propagation technique.

<u>Regulatory Strategies</u>

Use of “suppression” products –

Streptomycin is the only registered product in Canada that provides control as opposed to suppression of fire blight. In fact, at the present time there are no materials other than antibiotics that provide acceptable control of this disease worldwide. Products such as bacterial antagonists, gibberellin inhibitors, SAR inducers, and other experimental products provide varying levels of suppression when used alone. However, because not only a current season’s crop can be lost, but tree structure (e.g. death of whole branches) or whole trees (e.g. rootstock blight or severe tree/trunk blight), suppression alone is not a sustainable alternative for growers. The companies that produce these products and the world’s fire blight experts agree that at present, all these “suppression” products should be used together with streptomycin in an integrated program that targets fire blight pre-bloom (e.g. copper, bacterial antagonists like BlightBan), during bloom (streptomycin, cooper), and post-bloom (e.g. Apogee,). It is expected that these products would allow apple growers to reduce the amount of streptomycin used on an annual basis. Support from the regulator (PMRA) in facilitating the registration of "suppression" products (e.g. BlightBan, Serenade, Messenger) would be of benefit to help the industry better manage fire blight outbreaks.

Transition strategy for "control" products

Because of the unpredictable and potentially destructive nature of the disease, and its potential impact on the economic viability of the industry, growers need access to an efficacious control product (e.g. streptomycin) in years when weather conditions during bloom favour the rapid multiplication of fire blight bacteria. As documented earlier in this paper, millions of dollars of losses were incurred in the US when the disease was not adequately controlled in an epidemic year. A serious outbreak could decimate a localized geographic area where tree fruit production is concentrated (e.g. Niagara Peninsula). The fall-out could be the loss of livelihood for many growers, as well as potential indirect impacts on other sectors (e.g. the peach canning industry in Niagara).

Apple and pear growers are well aware of the risks associated with applying any pesticide, including the risks of resistance development within the pest population. A large majority of apple and pear growers use the Maryblyt or Cougarblight prediction models to time streptomycin sprays, dramatically reducing the unnecessary use of this product. Together with copper sprays in early spring to reduce bacterial inoculum and an integrated management strategy that includes a balanced nutrition program, predictive modelling, diligent pruning and removal of cankered wood, and other cultural techniques, fire blight can normally be kept at a manageable level.

The industry is supportive of all new tools and technologies and eager to implement integrated strategies for fire blight but need to continue to have access to streptomycin while other efficacious control products for fire blight are being developed. In this context, there is a need for streptomycin to continue to be available for conscientious use by growers, based on the use of predictive models, weather forecasts, and recommendations by IPM practitioners.

The industry has a clear need for the PMRA to communicate its position regarding streptomycin, and it needs a firm commitment from the regulator to work with industry in maintaining the streptomycin registration until an alternative is found. The formation of a national Ad-hoc Fire Blight Working Committee , with representatives from industry, provincial government, AAFC and PMRA, would be beneficial in developing an action plan for the long-term management of fire blight in this country. An action plan might include the following:

- Coordination and funding of efficacy testing of new products to manage fire blight
- Strategies for enticing companies to register products in Canada
- Support for joint registration of products in the U.S. and Canada
- Development of technology transfer programs
- Accessing funding for research and technology transfer priorities

Concurrently the industry, with the assistance of researchers and provincial extension staff, should maintain contacts with US counterparts so as to be aware of any new non-antibiotic materials considered for registration with use against fire blight and other new technology being developed. The sector should make the PMRA and AAFC's PMC aware of the interest in Canada, and encourage and support joint reviews for new active substances with potential as a fire blight management tool.

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Appendix I.
Examples of economic impact of fire blight in absence of streptomycin as a control agent

Scenario #1:

Super Spindle Apple Planting in Okanagan Valley, BC.

Specifics:

- 2.5' x 10' spacing, 1742 trees/acre
- based on 1999 cost of production data[1]

Assumptions:

- First crop in Year 2, full crop Year 6 onwards (36,000 lbs./acre yield)
- Breakeven year is Year 7
- Price received for fruit is $.25/lb
- Land cost, financing costs not included in calculations
- Any interest on profits not included
- NPV not calculated

Situation:
Cumulative loss if 1 acre of trees (Year 5) is destroyed by fire blight:

Impact on Break-Even Year:
Break-even year becomes Year 12 instead of Year 7 – a 5-year delay in which a $165,760/acre profit should have been realized.

Original Planting	
Gross Income (Year 2 thru 4)	$12,820
Total Direct Expenses (Planting Year thru Year 4)	($27,886)
Loss in Net Income (Year 5 thru 10)	($97,604)
Re-Plant (Year 6 is pre-plant year)	
Gross Income (Year 6 thru 12)	$79,124
Total Direct Expenses (Year 6 thru Year 12)	($33,582)

[1] *Assessing the Economic Impact and Establishment Cost of Replanting Orchards*, BCMAFF, November 1999

Appendix I. (continued)

Scenario #2:

Processing Bartlett Pear Planting in Niagara Peninsula, ON

Specifics:

- 201 trees/acre
- based on 2002 calculations[1]

Assumptions:

- First crop in Year 5, full crop Year 9 onwards (11.0 ton/acre yield)
- Breakeven year is Year 12
- Price received for fruit is $.25/lb
- Land cost, financing costs not included in calculations
- Any interest on profits not included
- NPV not calculated

Situation:
Cumulative loss if 1 acre of trees (Year 8) is destroyed by fire blight:

Impact on Break-Even Year:
Break-even year should have been Year 12. After losses to fire blight and re-plant, the grower is still at a net loss of $73,152/acre, when a profit of $11,836/acre should have been realized. The reality is that re-planting an acre of pears lost to fire blight is not economically viable.

Original Planting	
Gross Income (Year 5 thru 7)	$3,850
Total Direct Expenses (Planting Year thru Year 7)	($16,226)
Loss in Net Income (Year 8 thru 16)	($48,400)
Re-Plant (Year 6 is pre-plant year)	
Income (Year 8 thru 16)	$ 3,850
Total Direct Expenses (Year 6 thru Year 10)	($16,226)
TOTAL PROFIT/(LOSS) (Year 16)	**($73,152/acre)**

By Year 16 accumulated profit should have been $11,836/acre

[1]*Establishment and Production Costs for Tender Fruit: 2002 Economic Report*, OMAF

Appendix I (continued)

Scenario #3:

Vertical Axis Empire Apple Planting in Southern ON

Specifics:

- 450 trees/acre
- Based on 1995 and 1999 calculations[1]

Assumptions:

- First crop in Year 3, full crop Year 6 onwards (787 bu/acre yield)
- Breakeven year is Year 9
- Price received for fruit is $.17/lb
- Land cost not included, financing costs included in calculations
- Any interest on profits not included
- NPV not calculated

Situation:
Cumulative loss if 40% of bearing surface on 1 acre of trees (Year 15) to fire blight[2]

Economics:
Over the next 5 years, until the orchard returns to it's full bearing capacity, the grower experiences a net profit loss of $10,971/acre.

Original planting	
Gross Income (Year 15 to 20)	$32,912
Total Direct Expenses (year 15 to 20)	($14,019)
Net Profit (Loss)	$18,893
Planting affected by fire blight	
Income (Year 15 thru 19) (60%)	$16,456
Income (Year 20) (100%)	$ 5485
Total Direct Expenses (year 15 to 20) [3]	($14,019)
Net Profit (Loss)	$7,922
DIFFERENCE (LOSS)	**-$10,971/acre**

[1] *Cost of Production, High Density Supported Apple Orchards*, 1995, OMAF and *Cost of Production of Apples*, 1999, OMAF.
[2] Assumption: takes 4 years to return from 40% lost production to full production again.
[3] Direct costs maintained at 100% throughout (partially to compensate additional labour in pruning out fire blight in Years 16 to 19)

Appendix II. Materials registered for fire blight in the U.S. and their strengths and weaknesses

Material/ Manufacturer	Strengths	Weaknesses
Streptomycin (Streptomycin 17)	▪ Effective (superior) control of fire blight	▪ Regulatory status -antibiotic
Oxytetracycline (Mycoshield)	▪ Alternative for streptomycin where resistance exists (e.g. BC)	▪ Chances of registration in Canada slim – antibiotic ▪ Not as effective as streptomycin
Copper products	▪ Reduces overwintering inoculum	▪ Russeting on sensitive cultivars ▪ Not a "stand alone"
Aluminum-tris (Aliette)	▪	▪ Very inconsistent results in the US – suppression only
Pseudomonas fluorescens A506 (BlightBan A506)	▪ Good level of suppression when applied at beginning of bloom ▪ Biological – reduced risk	▪ Effective in reducing incidence in blossom blight, especially when followed by streptomycin ▪ Suppression only - not a "stand alone"
Bacillus subtillus (Serenade) .	▪ Good level of suppression when applied at beginning of bloom ▪ Biological – reduced risk	▪ Some positive results in NY when used in rotation with streptomycin ▪ Suppression only - not a "stand alone"
Harpin protein (Messenger)	▪ Good results in some trials ▪ Reduced risk ▪ "Turns on plant defence systems"	▪ Inconsistent results in trials in US ▪ Suppression only - not a "stand alone"
Prohexadione-calcium (Apogee)	▪ Growth suppression of terminal growth reduces susceptibility to FB ▪ Best used as a follow-up to material applied for blossom blight control	▪ Caution must be exercised on non-bearing trees, where shoot extension is desirable ▪ Suppression only - not a "stand alone"
Other materials not registered in the U.S. but showing potential:		
Oxylinic acid (Starner)	▪ Product is effective in Israel ▪ Trials have shown promising results in BC	▪ Not registered in U.S., registered in Israel
Pantoea agglomerans C9-1 (BlightBan C9-1)	▪ Up to 50% suppression in U.S. trials ▪ Biological – reduced risk ▪ Anticipated future registration in U.S.	▪ Effective in reducing incidence of blossom blight, especially when followed by streptomycin ▪ Generally performs somewhat better than *P. fluorescens*) ▪ Suppression only - not a "stand alone"
Flumequin (Firestop)	▪ Trials have shown promising results	▪ Not registered in US, no longer registered in France due to prohibitive cost.

Appendix III. Recommendations for Managing Fire Blight in Orchards

Tree Phenology	Management Practices
Dormant	If fire blight was present in the last growing season dormant pruning should become a two-step process: the first time through the orchard is to prune and remove all overwintering cankers, and the second time is the normal pruning process. Aggressively prune out <u>all</u> visible symptoms of fire blight to reduce the number and distribution of inoculum. Prune just below visible symptoms. During winter the bacteria are inactive and spread of disease through pruning tools is unlikely, however to reduce risk of bacterial spread further, dipping pruning tools in denatured alcohol or diluted bleach solution is recommended. Completely remove young trees where fire blight has moved into the trunk or rootstock. All "blighted" wood should be disposed of by burying or burning.
Delayed Dormant (Silver tip) or Green tip	Apply nitrogen fertilizer based on leaf and soil sampling conducted in the previous growing season. Avoiding excess nitrogen helps in reducing unnecessary vegetative growth, thereby reducing the susceptibility of green tissue to fire blight, and allowing early "hardening off" of terminal growth. Apply copper spray or Bordeaux mixture (copper + lime) to trees to help reduce initial fire blight bacteria populations. The role for copper in controlling fire blight is to provide an inhibitory barrier over all bark and bud surfaces thereby preventing the bacteria from colonizing these areas. For this to be effective, coverage must be thorough so a high volume spray is needed to completely wet all exposed surfaces on the tree surface. 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 less susceptible cultivars provides a safe haven for the bacteria to colonize and later be dispersed by honeybees and flies to open flowers of all cultivars, reducing, if not totally negating, the value of the treatment. ***<u>Caution</u>: Copper is highly phytotoxic to leaves and blossoms. Use only up to green tip. Apply as a Bordeaux mixture to increase degree of safety when using copper.*** Begin monitoring temperatures at green tip for use in fire blight prediction models. Begin inputting temperatures into either MaryBlyt© or Cougarblight prediction models.
Bloom period	Continue to input weather data and forecasts into MaryBlyt© or Cougarblight prediction models. Once blossoms begin to open, and when your prediction model recommends treatment, apply Streptomycin. Apply in sufficient volumes of water to achieve through coverage of all bark and leaf surfaces. Reapply in 2-3 days if "high risk" conditions persist. Do not apply on an alternate row middle basis. Limit to no more than 3 applications
Petal fall to bud set	Maintain a sound integrated pest management program for managing insect vectors (those with piercing-sucking mouthparts, i.e. aphids, leafhoppers, plant bugs) to reduce the potential for spread of shoot blight. Monitor orchards closely for early blight symptoms ("strikes", "Shepherd's crooking" of shoots) and remove promptly by ripping out or pruning. Cutting out infections as they appear is important in preventing further spread of the disease, especially if the number and size of infections is relatively low. Where symptoms of fire blight are severe and widespread, however, extensive cutting (except to salvage the central tree structure) can induce more shoot growth, prolonging the period of susceptibility. Pruning tools should be disinfected by dipping in denatured alcohol or a bleach solution after each cut. All pruned out wood must be removed from the orchard and buried or burned. A method that has proven useful in limiting the spread of active bacterial movement in wood is the **"ugly stub" method:** Fire blight bacteria can often be found in apparently healthy tissues 1 m (3 ft) or more in advance of visible symptoms. Research shows that simply cutting into colonized, but otherwise healthy limbs breaches the trees normal resistance mechanisms and may induce the formation of a small overwintering canker. Thus, when removing active strikes during the season: 1. Begin cutting when symptoms first appear, before extensive necrosis develops. 2. Make cuts 15-30 cm (6-12 in.) or more below the visible symptoms.

	3. Make cuts into wood that is at least 2 yr old or older. 4. Do not cut back to the next healthy limb or spur, but leave at least a 10-15 cm naked or "ugly" stub. Tool sterilization for this procedure does not seem to offer any significant advantage. The small cankers that are inevitably induced at the cut end of the stub are often less than ¼ in. deep and do not appear at all like the distinctive limb cankers pictured in most textbooks. 5. Remove all "ugly stubs" during the dormant period when the temperature is too cold for the bacteria to multiply. Marking stubs with a bright paint when they are first cut makes finding them easier during the dormant pruning period. Several cutting tours every 2 days may be needed to limit the number and distribution of bacterial sources for shoot blight and subsequent canker formation. Avoid extensive cutting that may stimulate vegetative growth and lengthen the period of shoot blight susceptibility. In some cases, where fire blight strikes are extremely numerous, it may be best to allow the disease to run its course and then aggressively prune out and remove all blighted wood in the following dormant season. Follow-up management in subsequent years will be required. Conduct leaf and/or soil sampling to aid in development of a sound nutrition program – healthy, “balanced” trees are better able to withstand bacterial infections.
Late summer	Although the risk for further fire blight infections is relatively low during the later part of the growing season, severe storms can still trigger a trauma blight incident, especially if blight has occurred earlier in the season. In those years when a second flush of shoot growth occurs late in the season, make sure potential insect vectors are controlled. All late season strikes should be cut out promptly.

Plates. Fire Blight Symptoms on Apple and Pear

(Photos courtesy of B.C. Ministry of Agriculture and Food and Fisheries, Michigan State University; Gordon Bonn;, EarthTramper Consulting Inc.)

Row 1. Overwintering canker in branch, fire blight in rootstock, dead rootstock
Row 2. Blossom blight, dead blossom cluster
Row 3. Bacteria oozing from shoot, shoot wilting, typical Shephard's crooking symptom
Row 4. Dead shoot, active canker in limb, advanced weeping canker
Row 5. Fire blight symptoms on fruit, infected pear, infected apple
Row 6. Heavily infected block of Jonagold
Row 7. Fire blight strikes throughout a tree, dead young tree, fire blight infected nursery

Row 1


Row 2

Row 3


Row 4

Row 5

Row 6

Row 7