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Critical Issue Report: Fire Blight Control Program in Organic Fruit

Grower Lessons and Emerging Research for Developing an Integrated Non-Antibiotic Fire Blight Control Program in Organic Fruit

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The Organic Center is pleased to present this publication, looking at lessons learned on organic methods for controlling the spread of fire blight without the use of antibiotics. Fire blight is a serious problem for apple and pear growers in the US; it is highly infectious and can kill entire trees. With growers now spending up to $20,000 per acre to establish an orchard, the risk of severe tree injury or loss from fire blight needs to be controlled.

In the past, the antibiotics streptomycin and oxytetracycline have been the key fire blight controls used by most organic growers. However, the use of oxytetracycline will sunset in October 2014, and streptomycin is likely to sunset soon thereafter, so growers will need to implement non-antibiotic control programs within the next year.

This publication is aimed at a grower audience, with reviews incorporated from growers, orchard managers, researchers, extension agents, and consultants. Our goal is to provide critically needed information on how to prevent fire blight from decimating apple and pear orchards without the use of antibiotics in time for the 2014 sunset of oxytetracycline, because the lack of current information on alternatives to antibiotic use in the prevention of fire blight could cause serious repercussions in the organic apple and pear industry. Recent polls done by David Granatstein, Sustainable Agriculture Specialist at Washington State University, show that some 70% or more of organic apple and pear producers in that state (the primary producer in the country) will consider switching some or all production to conventional management if an effective and reliable alternative for fire blight control is not available by the time oxytetracycline sunsets. This couldn't come at a worse time, since organic apple and pear demand is at an all-time high.

We hope that you find this information useful, and are able to integrate future information and new materials as they become available into these holistic practices.

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Abstract. U.S. organic apple and pear growers with fire blight prone cultivars have one growing season to test, evaluate, and adopt new successful non-antibiotic fire blight management tools. There is a gap between the phase-out of antibiotics in late 2014 and the final results of current research projects and the translation of this knowledge into actual organic orchard practices. This publication is meant to help fill that gap with experiential knowledge from growers who have implemented non-antibiotic fire blight control over the past decade, primarily in central Washington State, along with emerging research. There is no cure for fire blight, and there is no single 'silver bullet' (including antibiotics) that will prevent fire blight infection. Successful non-antibiotic fire blight control centers on combining orchard management practices into an integrated systems approach which is multi-faceted, and marries effective fire blight prevention with fungal control, insect control, bloom thinning, spray coverage, tree training, soil and foliar nutrients, and cultivar and root stock selection. Growers will need to evaluate ideas presented here in light of their particular orchard situation and align this information with new research and new products as they become available.

Important Note to Readers:

The following document contains references to various pesticides and other crop inputs that may be relevant to a non-antibiotic fire blight control program. These are not formal pest control recommendations, but ideas for growers to use in formulating their own program. Not all pesticides discussed are registered with the USEPA, or allowed in certain states. In addition to federal and state regulations, a pesticide must be compliant with the National Organic Program in order to be used on an organic farm. This generally involves approval from a materials review organization such as Organic Materials Review Institute (OMRI). Applicators are reminded that it is your responsibility to check the state registration status of a label before using the product to ensure lawful use and to obtain all necessary licenses, endorsements and permits in advance. Additionally, some pesticides reported in these resources may have been used under state-authorized experimental permits at rates higher than allowed on the label. Application of a pesticide to a crop or site that is not on the label is a violation of pesticide law and may subject the applicator to civil penalties up to $7,500. In addition, such an application may also result in illegal residues that could subject the crop to seizure or embargo action by your state department of agriculture and/or the U.S. Food and Drug Administration. Use of specific trade-mark brand names in this document does not constitute endorsement by the authors or validation of results from their use.

1. Introduction and Purpose

For the past several decades, the primary control of fire blight in organic production in the U.S. has been use of the antibiotics streptomycin and oxytetracycline. These antibiotic materials were allowed in organic production prior to the establishment of the National Organic Program (NOP) by some certifiers, and put on the original NOP list of Allowed Synthetics. The National Organic Standards Board (NOSB) has approved a proposal for the expiration (phase-out) of their use on October 21, 2014. As a result, U.S. organic apple and pear growers with fire blight-prone cultivars have one year to test, evaluate, and adopt new successful non-antibiotic fire blight management tools to avoid loss of organic certification. The intent of this publication is to present integrated non-antibiotic fire blight control options that have proven successful for some organic growers, mostly in the Pacific Northwest. A number of these options will not be fully tested and evaluated by researchers before the phase-out date. Those organic tree fruit growers affected by the NOSB antibiotic phase-out decision can benefit from this experiential information as well as from the research underway, some of which is guided by and validating what is reported here[1]. Most of the grower lessons learned are based on experience in the semi-arid regions of central Washington. However, initial research and unpublished data and experience from other more humid growing regions[2] have been included when available.

Organic apples and pears exported to Europe (EU) are not allowed to be treated with antibiotics. Thus, a number of growers producing for export have developed various approaches to non-antibiotic fire blight control. In Washington State for example, approximately 20% of the organic apple and pear growers have been EU compliant (have not used antibiotics for three or more years) at various periods over the last ten years (the percentage is lower for California organic pear growers). Harold Ostenson worked with many of these growers to develop and test alternatives. He spent twenty-five years as an organic orchardist and then became Organic Program Manager for a large fruit company committed to organic production. He worked with growers to evaluate new non-antibiotic approaches to fire blight control, and to integrate various strategies rather than looking for a single product replacement for antibiotics. This collective experience with non-antibiotic control can be drawn upon to help other growers adapt to the new rules that exclude antibiotics.

This publication is meant to help fill that gap and enable organic growers to retain their organic certification by increasing their knowledge of alternative non-antibiotic fire blight control methods, and their confidence in applying those methods. In the final analysis, this document is what the authors believe to be their 'best shot' at presenting

non-antibiotic FB control options with the greatest potential to be successful here and now. Rather than a formal extension publication based on peer-reviewed research, this report compiles lessons learned by growers and previously published studies, and is focused at a grower-centric audience. There is additional research underway that will add to our understanding of fire blight prevention, particularly with the USDA Organic Research and Education Initiative (OREI) project on organic fire blight control led by Dr. Ken Johnson of Oregon State University, with cooperators in Washington (Prof. Tim Smith) and California (Dr. Rachel Elkins). This project is generating very promising results[3], some based on new insight about fire blight biology and on new materials, and some validating organic practices successfully used by EU compliant growers. However, the OREI project will not be completed until 2015, with publications to follow. Thus, there is a gap between the phase-out of antibiotics in late 2014 and the final results of the research project and the translation of this knowledge into actual organic orchard practices, which this publication strives to fill. Readers are urged to consult the footnote section for clarifications and additional information on statements found in the text, and their origination: field experience, unpublished data references, researchers' comments, and best deductions from what we know now.

Over the next four years our knowledge pool about fire blight will grow as formal and informal testing of new organic-compliant materials[4] for fire blight control continue. Both researchers and organic growers are testing new products as they become available. For example, Blossom Protect™, a yeast bio-control product[5] new to the market in 2012, is one important recently approved addition to the list of organic materials used to combat fire blight. New copper products are being developed that contain a much lower concentrations of metal which may reduce the risk of creating surface defects on the fruit (russet) and reduce the risk of elevating soil copper levels. One such product is already available and OMRI approved (Cueva™)[6] with another (Previsto™) expected to be EPA registered in late 2014. Overall, the options for non-antibiotic fire blight control are increasing and will be available near-term.

This publication is based on both field experiences from organic growers and research trials and is aimed at a grower audience. It is understood from experience that no two orchards are the same, and that in the end, management, climate, equipment performance, and individual grower innovation will determine the best options for each grower's solution to successful non-antibiotic control of fire blight.

2. Management in Transitioning to Non-Antibiotic Fire Blight Control

The focus of this publication is on the most promising near-term practices and programs for non-antibiotic control of fire blight (FB). The target reader is an organic grower presently using antibiotics when needed, but facing the phase-out by the fall of 2014 to remain certified. Emphasis is placed on where the grower needs to re-focus his/her attention for FB control without use of antibiotics. The reference section found at the end provides web sites and articles where basic FB orchard management and general FB infection biology may be reviewed.

2.1. Unrealistic Options

Let's start by identifying some of the factors known to reduce FB susceptibility which look good on paper, but are unrealistic from a commercial organic business standpoint in the near-term.

(1) Plant less FB-susceptible cultivars

Presently two FB-prone cultivars represent over 50% of the U.S. organic apple production: Fuji and Gala. In Washington State, commercial production and sales of these two organic apple varieties represent between 5–6 million cartons (40-lb) or over $150 million FOB sales for the 2012 crop. It is unrealistic to assume that substituting a new FB resistant apple variety will overcome the popularity of these varieties with consumers in mass markets anytime soon. An informal survey of large tree nurseries in 2011 did not elicit any suggested alternative cultivars with significant FB resistance for larger commercial plantings. Midwest and Eastern growers who are direct marketing or already introducing their customers to scab-resistant varieties may have more near-term opportunities to choose varieties with decreased FB susceptibility and develop a market for them.

(2) Use less FB susceptible rootstocks

Selecting rootstocks to help control vigor associated with a specific FB prone cultivar makes good sense. But, FB resistant rootstocks, even paying extra for 'Geneva' strain rootstocks that have varying resistance to FB infection for example, make little economic sense if the selected commercial cultivar (scion) grafted on it is susceptible to FB and dies back and all production is lost for an extended period. The rootstock does not grow the commercial fruit. See Appendix 1 for more discussion of resistant cultivars and rootstocks as part of a long-term solution. Growers can plant a few trees of reputed resistant varieties now and begin evaluating their potential fit into a location and market.

2.2. Fire Blight Prediction Models

Several orchard management factors become more critical in non-antibiotic FB control. Current FB management relies on the use of weather-driven disease forecasting to indicate high infection risk and to trigger a control action. The switch to non-antibiotic control, especially with biocontrol products, will require more lead time than the current models allow for, leading to more spray applications in general. However, other sprays already being used can be integrated into a FB management program. Remember, every orchard situation is different and some of the following factors are applicable to your situation, while others are not. All of these factors contribute to the reduction in FB infections and together provide the basis for a non-antibiotic FB control systems approach.

2.3. General Management Considerations for Reducing Fire Blight Risk

- **Integrated systems approach.** There is no cure for FB, and there is no single 'silver bullet' that will prevent FB infection. Successful non-antibiotic FB control centers on integrating your orchard management practices into a systems approach that is multi-faceted, and combines effective FB prevention with fungal control, insect control, apple bloom thinning spray coverage, tree training, soil and foliar nutrients, and cultivar and root stock selection. Because most FB suppression sprays are the same materials already being applied against other organic orchard horticulture problems such as scab, mites, mildew, fruitlet thinning, and insect pest control (e.g., delayed dormant sprays of copper, oil, lime sulfur; fall sprays of oil, lime sulfur). Integrating your overall orchard spray program with effective FB suppression sprays is not as complex as it may seem. Specific FB systems approach factors for apples and pears will be addressed in detail below.

- **Tree training systems.** It is understood that growers are committed to their present orchard block plantings, but high density, eight-foot high 'pedestrian' (no ladders), two dimensional type plantings should be considered for FB prone cultivars in any apple or pear orchard renewal planning. This type of planting reduces the pressure to over-invigorate new plantings to fill space and reduces FB infection potential. The two-dimensional approach greatly improves the full foliage coverage required of FB control sprays (the same for scab control, etc.), and can transition tree pruning from winter to summer and early fall, thereby working during warm, dry conditions when pruning 'wounds' are less prone specifically to shoot blight infection. In this system, FB infection is detected earlier and damage can be minimized.

- **Crop load management.** Managing consistent and even crop loads from year to year reduces fire blight infection potential by controlling over-vigorous shoot growth in the 'off' production, biennial year. Crop load management of apples and some pear cultivars[7] for organic growers occurs during bloom when the potential for fire blight infection is usually the highest. Organic thinning to control apple fruit set usually involves a combination of materials including lime sulfur which provides FB suppression during bloom (Note: lime sulfur applications will be toxic to biocontrol materials such as BloomTime™, Blight Ban™, or Blossom Protect™ and should not be tank mixed). Bloom thinning, especially for apples, is a key component of a successful integrated systems approach program, because: (1) it compacts the bloom window and reduces bloom exposure to FB infection; (2) the same organic bloom thinning materials are effective against scab, mildew, and other fungal threats; (3) these materials suppress over-wintering pests such as aphids, leaf rollers, scale, and others, that can spread the FB bacteria; (4) a good bloom thinning program reduces excessive tree shoot growth in light crop years. The end of the bloom-thinning window marks a pivotal point in the annual horticulture fruit production cycle because many of the issues facing the organic grower for the rest of the season will be determined at this time: crop load, tree vigor management, fire blight infection potential, scab-mildew-fungus infection potential, pest level potential, and return bloom and next year's crop potential. Grower experience with these thinning materials led to formal field testing that validated FB suppression.

- **Equipment.** Helpful equipment and methods for minimizing spray costs while maximizing spray coverage include: (1) If a significant portion of the farm is dedicated to organic tree fruit growing, make a tower sprayer a high priority; (2) Don't over-crop trees; (3) Provide 'sun windows' in the canopy to improve both spray penetration and fruit quality; (4) If a ground power air blast sprayer is the only option for spray applications, consider 300 gallon per acre (GPA) nozzles on the top one-third of the sprayer application pattern, 200 GPA nozzles in the middle, and 100 GPA on the bottom third nozzles. This will 'throw' more spray higher and farther in the tops of the trees and reduce the fruit russet potential from material blast in the tree bottoms; (5) Invest in a good pH meter to insure that your tank mix is at a pH level which maximizes the survival of any antagonistic FB organisms you are applying.

- **Spray volumes.** There are two approaches to spraying: (1) use a low spray volume with high active material concentration, which still gives full canopy coverage while also keeping spray deposited on fruit from forming droplets on the calyxes which dry and turn black; and (2) use dilute spray volume in the 300 GPA range, with low active material rates so that the droplet residue concentration forming on fruit calyxes is too low to cause residue marking. Weather, spray equipment, pear cultivar mix and tree canopy size all contribute to the spray volume decision, so both of these options can be used effectively. High volume seems to hold an advantage, at least in the West, for pyslla control.

- **Pre-bloom foliar nutrient spray programs.** Pre-bloom nutrient sprays play an important role in an integrated FB control program because they accelerate tree leaf expansion and the startup of photosynthesis, resulting in a more compact, shortened bloom period, faster fruit set, and a reduction in FB infection exposure. Materials consisting of cytokines, fish products, and carbohydrates have been

found by growers to be very effective in apples and pears. An additional bonus of a condensed bloom is better bloom thinning results; less bi-annual bearing, consistent tree shoot vigor, larger fruit, and less shoot fire blight during the thirty days following bloom.

- **Environment.** There are ways to mitigate a spring bloom time environment that favors fire blight infection conditions, particularly in the Pacific Northwest:

  » Plant the most FB prone cultivars on the highest elevations available in the orchard. This will help lower humidity which promotes FB bacteria growth.

  » Avoid irrigating during bloom if possible. If irrigation is required, a drip (trickle) irrigation system would help keep orchard humidity lower. If you have wind machines for frost control, think about using them to increase air movement in your orchard to shorten the dry-out period during potential FB infection windows.

  » Reduce tree canopy wetness by striving to increase air flow and sunlight in your tree training systems, including two-dimensional canopies conducive to fast drying.

- **Sanitation.** In addition to standard orchard sanitation practices to control FB infection levels, consider a fall application of dilute lime sulfur and oil and/or copper just prior to leaf drop. This action may reduce overwintering pests, scab, and FB inoculum levels. The spray should be timed late enough that predator insect populations have ceased to be active. Sprays help dry out cankers and reduce insect transfer that only takes place on the surface. A mix of horticulture oil with copper painted on trunks in late winter has been used by growers for 20 years and is very effective in curing overwintering FB cankers and drying them up prior to spring. The copper treats the cambium layer. In many orchards, the copper/oil mix is still visible in subsequent years with no new canker activity.

- **Vigor control.** While some worry that transitioning to organic results in less production, less tree vigor, and smaller fruit, for many organic growers, this is not the case. Tree vigor can be controlled in organic orchards while producing prime sizes and volumes of fruit. Some techniques to consider:

  » Reduce dormant pruning and move to controlling growth in a summer and early fall pruning program. This will help reduce excessive spring shoot growth. This technique has worked well in the Northwest for reducing shoot blight the following year.

  » Use a steady diet of compost and build up the soil biology and nutrient reserve which will keep tree canopy and fruit production levels in balance.

  » Aggressively pursue pre-bloom foliar sprays to produce strong flowers, and shorten the bloom window. This leads to larger fruit than by applying more N fertilizer to the soil. This program reduces the excess vigor potential that leads to increased FB damage.

  » Aggressively bloom thin to increase fruit size, maintain consistent crop loads, improve fruit color, and stay out of biennial bearing.

  » Two general comments supporting a reduction in FB susceptibility: (1) Most orchards need the same amount of actual calcium applied each year as nitrogen; (2) Sulfur applied in low concentration with full canopy coverage in early June will help to set tree shoot terminal buds, reduce shoot blight, and counter aphids and mildew. Both of these actions[8] improve the tree nutritional balance, reduce vigorous green shoot growth, reduce FB opportunities and increase fruit size and quality parameters.

3. Integrated Systems Approach to Non-Antibiotic Control of Fire Blight in Apples

The following discussion is based on organic grower lessons learned, as well as findings and assumptions from preliminary data from research in progress. It focuses on spray material products that will complement the cultural measures described above. The basic EU program in the past involved a pre-bloom copper where cankers were present on trees, sprays of lime sulfur with or without oil, followed by Bloom Time™, and then by Serenade MAX™, along with the cultural measures. Since then, new materials and data have become available, and these are reflected in the comments that follow. Growers will need to consider all information in light of their specific orchard situation and craft a plan that is compatible with it. Not all organic materials discussed are approved for use in specific states. Always check your state pesticide regulations and with your organic certifier before using a new organic material.

- **Resetting the Stage for Non-antibiotic FB Control.** For most organic growers, the ideal solution to losing antibiotics is finding an approved replacement material that performs as consistently and as well as antibiotics during the bloom infection period. This has been a common approach for research as well: What organic product/material tested against antibiotics equals or outperforms antibiotic control (one on one testing)? Until recently, the synergistic effect of combining organic control materials in a systems approach has not been extensively examined[9]. Thus, there are limited data to support a specific antibiotic replacement plan. While the research continues, an integrated approach can be proposed based on the existing data, new materials, and the experience and success of those organic growers who have not been using antibiotics for a number of years and have retained FB control. The discussion below is organized by the developmental stage of the apple buds/flowers.

- **Dormant Stage to Tight Cluster Stage [silver tip, green tip, half-inch green, tight cluster].** In an integrated non-antibiotic FB control program, spray applications during these early apple bud development stages will dictate arthropod pest and disease control, as well as crop load success for the entire growing season. There are several horticulture actions occurring during these early stages that will be key to successful control of FB during bloom and after.

  » The more susceptible your cultivar is to russetting, the more intense the spray program must be during these early spring bud stages because from tight cluster bud development stage and thereafter, softer spray programs are necessary to minimize fruit russet.

  » Use active organic coppers, combined with or separate from lime sulfur and oil in dilute sprays of 200–500 gallons/acre with full coverage on every row. This period offers the best opportunity to effectively control over-wintering insect and mite pests, and damaging fungi for the remainder of the growing season. During this time, dilute sprays are a better control investment than less water and more concentrated levels of spray materials.

  » Spraying every other row with lower water spray rates [e.g.,100 GPA] and an airblast sprayer during this period will normally result in a requirement for extra sprays later when foliage and fruit are exposed and the potential for burn and russet are high.

  » This is the time to be bold with all your orchard control sprays. This is also the time when sprays will have a minimal impact on beneficial insects.

- **Pink Bud Stage through 50% Bloom.** These stages are critical to an integrated control program because: (1) warmer temperatures and conditions including bloom favor FB infection; and (2) exposure of the flower and developing fruitlets to the strongest FB control materials also lead to fruit russet and potential loss to the fresh market. It is preferable to use 'softer' materials that generally address a single orchard problem category: only pest control, or fungal control, or crop load management. The following statements are germane to the integrated FB control program during these stages:

  » FB is slow to develop during these stages especially if there has been an aggressive dilute copper spray program applied during the delayed dormant bud stage. The FB focus remains on suppression and prevention of FB bacterial growth and flower colonization during these stages.

  » For most organic apple growing regions, the sprays applied during this period need to: (1) inhibit FB, scab, and mildew growth, and cedar-apple and quince rust control in some Eastern areas, (2) inhibit insect pest pressure, (3) thin crop loads, and (4) not russet fruit.

  » Spray water volumes need to move from dilute (200–400 GPA) to semi-dilute volumes (100–200 GPA) to reduce the potential for leaf/flower burn and fruit russet[10].

  » Fatty acid soluble copper materials (e.g. Cueva™) should be considered rather than active copper products during this period to control scab, and FB bacteria growth, and to minimize fruit marking[11]. An upcoming lime sulfur thinning spray can provide mildew control at that time.

  » If your preferred integrated program uses BloomTime™ to inhibit FB bacteria growth on flower stigmas, then application(s) should occur by 50% bloom. Preliminary data indicate that FB biocontrol products like BloomTime™ and Blossom Protect™ will survive petal fall and post petal fall applications of Cueva™ or the soluble copper Previsto™ (not yet approved for use) with minimal loss in microbial counts[12]. Tank mixing these materials is probably not a good idea. None of these products will have an effect on controlling emerging populations of over-wintering insect pests.

  » Lime sulfur or lime sulfur plus oil can be used on apples during this time, but these materials will reduce populations of desirable FB antagonistic microbes. Antagonistic microbes targeting FB growth on flower stigmas or nectaries should not be used simultaneously with a lime sulfur program. Biocontrol products should be used after lime sulfur applications to maintain their efficacy[13].

- **Full Bloom Stage.** Regardless of whether you use antibiotics or not, there is no cure for FB. If the organic FB control plan has been to wait until FB models indicate an infection period has occurred, then it will be difficult to suppress FB infection during bloom, especially in younger fruit tree blocks. One of the main purposes of the integrated FB control program is to initiate a multiple spray program early in the spring growth cycle that has an accumulated effect on minimizing the potential for FB bacteria to infect during bloom. It is during this stage (full bloom) when flowers have the greatest risk of infection as the FB bacteria have a direct route into the plant via the flower nectary[14]. This is also the time when it is most difficult for a grower to concentrate on only FB control since this period is also a critical management period for controlling scab, mildew, insect pest emergence, and organically managing fruit set, crop load, and return bloom. Failure to manage any one of these challenges during this stage will result in a season long or even longer management recovery effort often at the expense of lower fruit quality and lost revenues.

- » Lime sulfur or lime sulfur + oil with 200 GPA spray volume are considered among the best spray mix options during bloom[15]. This mix suppresses scab, overwintering insect pest emergence, mildew, scale, and fire blight, while compacting the bloom window (shortening FB nectary infection periods), and reducing tree flower populations (especially late bloom). Experienced growers use 2–3 applications of bloom thinning spray in the 200 GPA spray volume range every 3–4 days to cover an 8–12 day bloom window. Even at low lime sulfur percent by volume, especially with low volumes of oil, good results in addressing the multiple challenges have been regularly achieved. Complete tree canopy spray coverage has been the differentiating factor.
- » While lime sulfur applications suppress beneficial organisms in FB biocontrol products, in most cases, the lime sulfur option trumps these and other FB control options because of its multiple simultaneous actions on various diseases, insect pests, bloom window compaction, and crop load reduction.
- » Research trials[16] have shown good results in suppressing FB when biocontrol materials directed at apple flower nectary infection have been applied a day after the last bloom period lime sulfur application. When a FB control bacteria or yeast-based product, such as Blossom Protect™ is introduced after lime sulfur, a much higher growth rate of the FB antagonistic organism occurs than without the lime sulfur due to elimination of most competing organisms by the lime sulfur[17], providing improved protection from FB flower nectary infection at a critical point in the FB infection cycle.
- » Soluble coppers might be the option of choice after lime sulfur bloom applications rather than biologicals to reduce the russet potential from high accumulations of bacteria/yeast on russet-prone apple cultivars under extended wet and humid conditions. The new soluble coppers, like the OMRI-approved Cueva™ (not available in all states), have much lower rates of copper (metallic copper equivalent 1.8%). More research is needed to know whether these new soluble coppers will provide better FB control with a lower risk of late bloom fruit russet compared to standard metallic copper materials[18]. There is probably no spray material option applied during this time that does not carry some risk of fruit russet., In most cases, spraying apples post bloom more often with higher rates of water, and lower active spray material concentrations, compared to spraying higher rates of spray material in lower water concentrations, sprayed over a longer window, will help to minimize russet.
- » If it is particularly wet (rain or high humidity) during the later portion of bloom, a spray combination of Serenade Optimum™, or similar biological material, or an organic SAR (Sytemic Aquired Resistence) product such as Regalia™ [19], with or without wettable sulfur may be a good option against FB, scab, mildew, and other fungi. An initial trial in Oregon found that a Serenade™ spray may reduce fruit russet on russet-prone cultivars caused by earlier applications of yeast when yeast residues remain on the fruit and become subject to extended wet conditions[20].
- » Under most apple bloom stage conditions in central Washington State, and the more humid conditions in western Oregon, results from an organic spray program consisting of: (1) lime sulfur with or without oil; (2) followed by Blossom Protect™ (3) followed by a soluble copper, (4) followed by Serenade™ have been the same or better than current standard antibiotic spray programs, with minimum fruit russet[21]. This integrated approach also suppresses other problematic fungi and pests with minimum impact on emerging beneficial insect populations.
- » Under heavy scab pressure, it may be necessary to go from the last lime sulfur treatments at bloom directly to a soluble copper program because the bio-fungicide option against FB, Blossom Protect™, will not prevent scab infection.

- **Petal fall–Post Petal fall [+30 days] Stage.** This post bloom stage becomes more complex in terms of an integrated systems control program because of a very broad range of horticultural challenges: (1) post bloom FB shoot blight; (2) emerging insect pests; (3) emerging beneficial insect populations; (4) continued need for scab and other fungal control; (5) full apple leaf expansion leading to more difficult full canopy spray coverage; (6) spray wash off by rain; (7) fruit sunburn, spray marking and russet. This is also the time when orchard temperatures warm and, when accompanied by rain, FB bacteria can rapidly infect late bloom on one-year old wood and accelerate shoot growth and shoot blight on new growth. This is the stage where spray mix compatibility, coupled with timely spray responses targeting a broad range of fruit and tree quality threats, becomes a critical integrated control challenge for the organic tree fruit grower. Spray material selection and timing during this period will determine the intensity and the number of applications for the remainder of the growing season needed to emerge with high quality fresh market fruit. Points to consider in formulating integrated systems approaches during this time period:

» For young apple blocks on a high nitrogen diet focused on 'filling the space', it will be difficult to control shoot blight if warm and wet conditions persist. The optimum organic spray program in this situation would utilize soluble copper applications preventatively. Currently there is a problem with the soluble copper approach since Previsto™ is not registered and Cueva™ (also not approved in some States) has a use label that ends at petal fall specifically for FB control. Experience with these products is limited in terms of russet potential and FB control. Cueva™ is labeled for post petal fall use (up to 30 days) for scab, sooty blotch, cedar-apple rust, and flyspeck. It is likely that these fungal diseases will be present at some level in most growing regions during this fruit development phase and require a preventative spray program which may include Cueva™. All coppers carry some risk of fruit russet. One year of data from Virginia indicated that there may be a fruit russet reduction potential in combining Cueva™ with a biological material like Double Nickel™ over applying copper alone[22]. All growers are advised to test (apply to 2–3 tree rows) this material for russet on each cultivar and tank mix before general use in their integrated programs. Orchard conditions and especially water pH levels differ at every location and affect product reaction and results (the same would apply to Previsto™ once registered for use). Lower tank pH will increase the fruit russet potential of copper based materials.

» If the integrated FB control program after lime sulfur consists of Blossom Protect™ followed by a soluble copper application (a successful FB control based on preliminary trials), additional soluble copper sprays at petal fall can proceed if required under a forecast of relative dry weather. This is especially true if scab and/or shoot blight are concurrently the major concern. Consider adding a biological, or SAR product, or Kaligreen™ with the soluble copper if scab or mildew infection potential is high. In the event that petal fall and post petal fall phases are met with heavy rain or extended high humidity conditions, a Serenade™ application should be initiated prior to forecasted rain. This specific action has been found to reduce yeast levels which have been growing since the Blossom Protect™ application. Without a yeast reduction, there is an increased russet potential under extended wet weather conditions[23].

» When addressing an integrated systems approach at petal fall and post petal fall with russet prone apple cultivars, non-lime sulfur and non-copper program alternatives may be a better approach to reduce russet potential. Although specific requirements will vary at each orchard, here are some options and comments to consider:

» (1) Using Serenade Optimum™ at petal fall following Blossom Protect™ and a soluble copper during the later stages of bloom will provide FB and fungal control with minimal risk of fruit russet; (2) Adding organic Novagib™ or Provide™ in conjunction with Serenade™ may provide improved russet control and promote apple size; (3) When insect pest control measures are required, adding insecticides to the Serenade™ spray tank mixture , such as B.t., Codling Moth Granulosis Virus, or Entrust™ (the latter for Plum Curculio, Apple Weevil threats, etc.), results in a more compatible spray mix with less fruit russet potential than combining these materials with a soluble copper, either as a tank mix or separate application. There is little actual experience with either approach, but early indications are that Serenade™ carries the lowest risk of russet on russet prone varieties of any FB control material; (4) This tank mix should be compatible with organic chelated micronutrients; (5) Adding wettable sulfur to a tank mix with Serenade will increase the mix effectiveness against scab and mildew (use caution in hot weather if adding sulfur).

» If shoot blight after petal fall is a major threat to the orchard, multiple applications of soluble copper are probably the best approach even at the expense of fruit russet. Controlling overly vigorous new growth via horticultural practices should also be a high priority. Control of chewing and sucking insect pests during this stage (e.g., aphids, stink bugs, white flies) is important as they can be a factor in the spread of the FB bacteria that will cause shoot blight.

4. Integrated Systems Approach to Non-Antibiotic Control of Fire Blight in Pears

Organic pear growers face a range of concurrent challenges during the FB infection season depending on their geographic region including pear psylla (WA, CA), mites (CA), mildew (depending on variety), spray-induced fruit russet, extended wet conditions, and frost. These challenges are exacerbated by large tree canopies (spray coverage issues) and aged plantings (many d'Anjou pear blocks are over 50 years old, and while FB spreads slower in these trees, they may harbor more pests and disease).

There are additional issues for pear growers that are of less concern for organic apple growers: (1) the organic wholesale fresh pear market does not provide a price premium for small pears. In fact, in most years small sized (size 120 and smaller) organic pears are worth less than conventionally grown pears of the same size; (2) good non-antibiotic FB control options used post petal fall in apples, such as lime sulfur and copper, present a high risk for marking and skin burn on pears; and (3) in many orchards, pears are planted in the 'cold spots' because pears generally survive frost better than most apple varieties (pears have 7 flowers per cluster, apples 5 flowers), and both FB and russet may be more likely in these locations due to higher humidity and dew, and a tendency for later bloom when temperatures are warmer. New FB resistant cultivars have yet to move into wide commercial production (see Appendix 1). Organic pear growers often live close to their profit lines while being challenged with several hard-to-manage horticulture issues. The move to non-antibiotic FB control adds more complexity to an already involved and expensive spray program. With this background in mind, let us address non-antibiotic integrated FB control in pears. The discussion below focuses on spray material products that will complement the cultural measures described in Section 2. Not all organic materials discussed are approved for use in specific states. Always check your state pesticide regulations and with your organic certifier before using a new organic material.

Resetting the Stage for Integrated Non-Antibiotic FB Control in Pears.

For pears, FB is primarily a bloom blight event with the exception of the Bosc variety, which is subject to both bloom and shoot blight. For many organic pear growers, pre-bloom sprays are focused on psylla control (and rust mites in CA), possibly scab and mildew; bloom focuses on antibiotic control of FB if infection criteria are reached; and post-bloom is occupied by spray programs to control psylla, fungi, and FB without russetting the pear. Without antibiotic use, integrated FB control measures will need to be more intense in the pre-bloom stages in an attempt to reduce FB bacterial growth potential in the bloom window as much as possible.

Currently, less research data on non-antibiotic integrated FB control in pear exist than for apples. For the most part, the following discussion points will reflect a combination of grower and consultant field experience, one-on-one FB control material research trials, limited two material integrated research trials, and best guess assumptions based on this information. Over the next several years a number of these expressed assumptions will be investigated by various on-going research projects, but little additional research data on non-antibiotic FB control in pears will be published prior to the phase-out of antibiotics. Most of the experience derives from central Washington. Readers are reminded to read the caveats presented herein on the title page under "Important Note to Readers".

- **Dormant Stage to Tight Cluster Stage.** These early stages are most critical to season long successful management of the growers' overall integrated systems approach in pears. For most organic pear growers this means executing a successful integrated spray program that suppresses and controls psylla egg laying and emerging populations; suppresses overwintering mites and mealy bugs, pear scab and mildew; and reduces overwintering FB bacteria. Frequent fall spray applications using materials described here for spring will greatly help control large populations of overwintering fungi and pest insects and greatly improve the outcome of the spring integrated spray control program. Lack of consistent good suppression across the board on all pear spray targets by the tight cluster stage the following spring is a clear sign that a fall integrated control program is needed.

  An added factor making integrated spray application decisions more specific, diverse and difficult to manage in each pear block situation is the variation among pear cultivars in their propensity to russet, coupled with the grower's target markets (fresh vs. processor). Early bud stage sprays (up to tight cluster) provide the best opportunity to apply the strongest, most likely to russet materials, with the least risk of fruit damage. Here are some of the integrated systems approach considerations:

  - During this window, pear psylla and pear scab control must be applied or these pests will be very difficult to control later in the season.
  - This is the window to be most aggressive with high volumes of spray, and high concentrations[24] of spray materials.
  - During these first 4 stages of bud development, typical integrated control sprays will consist of:
    - 2 separate applications of kaolin clay to suppress psylla egg laying. The applications will normally include summer (light) oil to desiccate deposited psylla eggs.

- An application of fixed copper and oil for overwintering disease control including FB and scab.
- An application of lime sulfur[25] and oil for FB, psylla, scab, scale, and emerging pest insects
- Often these integrated control sprays are combined, for example: kaolin clay, plus lime sulfur, and possibly very low percent summer oil.

» With female psylla laying up to 500 eggs each, it is difficult to organically control psylla populations by suppression methods only. Therefore, if 'beating tray' counts of over-wintering adult psylla are high, thought should be given to the use of organic pyrethrum sprays.[26] Since this material has very short efficacy, application conditions are critical. Warm, sunny early afternoon application timing can be very effective in psylla reduction and suppression of egg laying[27].

» Soluble copper should be considered at tight cluster as a protective spray against mildew, scab, and FB. This spray will cover fungi targets into the mid-bloom window and delay FB bacterial build up. This action will most likely reduce the number of flower nectary infection suppression sprays required and reduce the russet potential on the smooth-skinned pear varieties[28].

- **First White Stage through 50% Bloom.** During this period copper sprays at lower rates with good canopy coverage will continue to provide targeted disease control on cultivars (Bosc, processors, etc.) where low levels of russet are not an issue. On smooth skinned varieties for the fresh market, emphasis needs to focus on FB, scab, and mildew control with organic biocontrol materials. During this bud stage window it will be difficult to suppress mites and pyslla[29] and control efforts against these pear pests should be directed towards materials applied during early tight cluster stage, and then resumed at petal fall. In addition, biocontrol materials are needed that can prevent FB bacterial growth on flower stigmas. Fixed copper and soluble copper sprays applied in earlier bud development stages should result in retarding FB bacteria growth during this bud development window and improve biocontrol material efficacy in this stage when russet is more of an issue[30].

» If relatively dry weather is being projected during this time, materials like BloomTime™, Blossom Protect™, or potentially Previsto™ for FB suppression are considered good options on most pear varieties. If there is a scab history in the pear block, a soluble copper mix may be a better choice to target FB, mildew, and scab.

» If rain, wet, and high humidity conditions persist during this window, materials which have low russet potential under these conditions are more appropriate. Yeast-based biopesticides and copper-based materials may need to be exchanged for Serenade MAX™/Serenade Optimum™, or DoubleNickel55™/DoubleNickelLC™ biopesticides which have lower russet potential. At this point, there are more research results about the russet potential of new materials under poor drying conditions, or hot weather, than about the effectiveness of low russet non-antibiotic substitute materials against FB, scab, etc. in an integrated approach. Growers should be testing different organic material options under poor weather conditions to determine which new material options perform the best and russet the least under their specific orchard conditions.

» Organic integrated psylla control options are limited during the bloom window. Enhancing beneficial insects can provide meaningful control[31]. One successful tactic being used more and more by growers is inserting large numbers of pyslla predatory insects (e.g., lacewing larvae)[32]. There are also options to attract more adult lacewings into the orchard[33]. These tactics are required to accelerate predatory insect control of young emerging pyslla and prevent pyslla juice marking of the new pears.

- **Full Bloom Stage.** During this stage, flowers have the greatest potential for infection if FB bacteria populations increase and are able to move to the flower nectary. This is also the most critical management period for controlling scab, mildew, and insect pest emergence. Failure to manage any one of these challenges during this stage will result in a season long or even longer management recovery effort often at the expense of lower fruit quality and lost revenues.

» Preliminary research investigations have shown that yeast followed by soluble copper during this timeframe resulted in better FB control than antibiotics. Both of these approaches focus on preventing FB flower nectary infection, and materials targeting flower stigmas have limited effectiveness as bloom development proceeds.

» Russet problems are of minimal concern when yeast and copper remain on the skin of russetted pear cultivars, such as Bosc, or Bartlett processor grades under extended wet conditions. Although the Bosc pear is quite susceptible to flower and shoot blight, FB control is achievable with current non-antibiotic organic materials because increased skin russet for the fresh market is not an issue. In wetter climates, with more difficult FB conditions, planting and maintaining russet pear cultivar orchard blocks will be advantageous for management and monetary return over smooth skinned d'Anjou type varieties. Orchard organization and planning should be arranged accordingly in terms of long-term sustainability of the farm.

» In scenarios where pear scab is a significant issue, integrated FB control programs may require going directly

to soluble copper applications at bloom since Blossom Protect™ and BloomTime™ are limited to FB control only.
- » Initial research[34] shows that Serenade™ can reduce yeast populations by up to 40%. Serenade™ use after yeast application under projected extended wet weather conditions may benefit smooth skinned pear varieties by reducing russet from the yeast.

- **Petal fall–Post Petal Fall [+30 days] Stage.** This stage for controlling FB is complicated by warmer temperatures conducive to FB infection, emerging populations of pyslla, and increased potential for pear russet. At the same time, emerging foliage and typically larger, older, pear canopy structure make spray coverage and good spray material effectiveness more difficult. It is within this environment that a multifaceted integrated systems approach needs to be effectively executed. Some of the factors to consider during this window include the following:
  - » Grower experience has shown that weekly full cover sprays are needed for thirty days after petal fall (longer in CA) to avoid late side bloom FB infection, and shoot blight. This will be especially true for Bosc varieties and for regions with extended 'rat-tail' bloom (e.g., in CA, Starkrimson, Bartlett).
  - » Late rat-tail bloom is often more subject to FB infection because in warmer temperatures FB bacteria grow faster than aging antagonistic bacteria or yeast applied at bloom or petal fall. Additional protective sprays are required for late bloom.
  - » Overall, post petal fall sprays of soluble copper offer good FB control, while covering pear blocks for pear scab and mildew. For the most russet prone pear cultivars, selecting a Serenade™ product or DoubleNickel™ product will still provide control of scab, mildew, and FB with the potential to lower russet risk under wet conditions. Canopy spray coverage is most important during this timeframe.
  - » FB models such as Cougar Blight or MARYBLYT should continue to be used to indicate high FB potential infection periods. Models will identify spray application windows where shortened intervals between spray applications could reduce infection potential. The start of pre-bloom preventive FB sprays cannot be indicated by the models, as is the common practice in antibiotic FB control programs. Some biocontrol products require longer lead times to reach their highest potential against FB bacterial infection. A model alert of high infection risk may be too late for effective control by some of the non-antibiotic materials currently available.

5. Emerging Research and Control Options

There will be limited new research results between now and the October 2014 antibiotic use phase-out date set by NOP. For the most part, in the single remaining fire blight season (spring 2014), each organic tree fruit grower will be the prime researcher on their orchard blocks in terms of testing and evaluating the best integrated systems approach to controlling fire blight without antibiotics. Outside help for the most part will come from one more season of research test data on emerging new materials that continue to perform with high levels of fire blight prevention, but most of all from limited test results with integrated control research where a combination of products has shown FB control comparable to an antibiotic control.

Here are some of the research results and emerging products that growers will or will not have access to as the spring 2014 fire blight control season commences:

- Indications are that in 2014 organic tree fruit growers will have one soluble copper product (Cueva™) registered (not in all states) and OMRI approved for FB, scab, and other fungi control. The advantage of this material is that it is low in metallic copper content, should be less prone to cause fruit russet, and has minimal negative effect on Blossom Protect™ yeast levels. However, researchers in eastern states have not found any copper that consistently suppresses fire blight without causing some increased russet[35]. Combining a biological or SAR with a soluble copper may allow for FB control with lower copper use and lower risk of russet.

- More data will be available from the previous three years of research on integrated non-antibiotic FB control with combinations of fixed copper, bio-control, oil, lime sulfur, and soluble coppers.

- There will be additional data on combinations of yeast (*Aureobasidium pullulans*) and/or soluble coppers followed by bactericides, such as *Bacillus amyfoliquefaciens* and *Bacillus subtilis* to provide post petal-fall FB control while reducing the fruit russet potential.

- The product mix for FB control will continue to change. Previsto™, another soluble copper, is projected for EPA registration in late 2014, but this is not guaranteed. An Italian company is marketing a bacteriophage that attacks the fire blight bacterium, and similar research is underway at Agriculture Canada and the U.S. One research group has shown in laboratory studies that a phage can infect and kill a fire blight cell in as little as 20 minutes. Products may also disappear if a manufacturer finds them to be no longer profitable.

Beyond next spring, there are several other potentially helpful options coming:

- 'Geneva' series apple rootstocks should become available in commercial quantities for orchard renewal in the next few years. Evaluation of these in different growing regions continues[36] to determine their level of fire blight tolerance and expression of other desirable traits. Growers will need to order trees in advance in order to secure the desired scion/rootstock combination.

- Several fire blight tolerant pear cultivars are available as a result of breeding programs (see Appendix 1) and have some track record on which to base potential consumer and grower acceptance. Getting one commercialized to where extensive plantings can be undertaken is the challenge. Small plantings can be done to test the new varieties in your location and explore consumer acceptance. Choices are less clear for apple at this time, but more focused breeding on fire blight resistance is underway using marker-assisted breeding and natural resistance found in wild apple species.

- Currently there are laboratory capabilities to measure FB bacterial levels in flowers. One process uses Loop-Mediated Isothermal Amplification technology[37] (LAMP). This technology allows for monitoring and measuring FB bacterial levels (currently about 24 hours to get results) and gives the grower insight into the best spray timing and the level of response required to avoid serious FB infection. There are companies currently working to develop LAMP technology suitable for field use by growers or consultants, with a potential to have results in 20 minutes at a reasonable cost. While the field level capability most likely won't be available by the antibiotic phase-out date, it is possible that in the next several years growers will use this technology starting at first-bloom for near real-time orchard monitoring, understanding the distribution of FB in their orchard, the levels of inoculum, and their population growth.

Notes

1. For example, view the eOrganic webinar by Dr. Ken Johnson, Oregon State University, which presents his most recent findings from a USDA-OREI research project on organic non-antibiotic fire blight control. http://www.extension.org/pages/62448/fire-blight-control-in-organic-pome-fruit-systems-under-the-proposed-non-antibiotic-standard#.Uh-2-X9BK24
2. Includes western Oregon, parts of California, Michigan, and eastern states.
3. Some early results are published in: Johnson, K.B. and Temple, T. 2013. Evaluation of strategies for fire blight control in organic pome fruit without antibiotics. *Plant Disease* 97:402–409.
4. Examples of this sort of testing can be seen at http://www.tfrec.wsu.edu/pdfs/P2397.pdf.
5. Resources from the product distributor and manufacturer http://westbridge.com/products-pdf-documents/BlossomProtectTECH.pdf ; http://www.bio-ferm.com/en/products/blossom-protect/
6. Information from the product manufacturer http://www.certisusa.com/pest_management_products/biochemicals/cueva_fungicide_concentrate.htm
7. "Pear crop load management and rootstock field testing." Tory Schmidt, Washington Tree Fruit Research Commission, Wenatchee, WA. http://jenny.tfrec.wsu.edu/wtfrc/core.php?rout=displtxt&start=101&cid=548
8. Based on grower experience. Pear growers experiencing small fruit size have often put on additional N, leading to more succulent shoot growth and greater fire blight risk with no fruit size increase, when instead a sulfur application was needed (most plants need nitrogen and sulfur in a ratio of 10:1 in order to build proteins).
9. Research on integrating different materials to target different stages of the disease: Stockwell, V.O., Temple, T.N., Johnson, K.B., and Loper, J.E. 2008. Integrated control of fire blight with antagonists and oxytetracycline. 793:383–390; Johnson, K.B. and Temple, T. 2013. Evaluation of strategies for fire blight control in organic pome fruit without antibiotics. *Plant Disease* 97:402–409.
10. Depending on the situation, sprays need to have lower concentrations of chemicals in the same water volumes post bloom, or you have to concentrate spray chemicals in low volumes of water in small droplets to prevent chemical run off on fruit and leaves and resultant burn or russet.
11. Smith, T. 2012. Improving the management of two critical pome fruit diseases. Research Report, WA Tree Fruit Research Commission. http://jenny.tfrec.wsu.edu/wtfrc/core.php?rout=displtxt&start=139&cid=529 ; and T. Smith, personal communication.
12. From Dr. K. Johnson, unpublished preliminary data. Previsto™ sprayed after Blossom Protect™ caused about a 10% decline in the yeast population.
13. From Dr. K. Johnson, unpublished preliminary data. Serenade Optimum™ sprayed after Blossom Protect™ caused about a 40% decline in the yeast population.
14. See K. Johnson webinar on organic non-antibiotic fire blight control. http://www.extension.org/pages/62448/fire-blight-control-in-organic-pome-fruit-systems-under-the-proposed-non-antibiotic-standard#.Uh-2-X9BK24. An individual blossom is susceptible the instant it opens. It takes some time for the bacterial population to build to an infective level, but that often occurs on the stigmas of adjacent flowers which opened earlier. The normal route of infection in the flower is the nectary.
15. Johnson, K.B. and Temple, T. 2013. Evaluation of strategies for fire blight control in organic pome fruit without antibiotics. *Plant Disease* 97:402–409. This practice is being used in central WA and parts of central CA.
16. Johnson, K.B. and Temple, T. 2013. Evaluation of strategies for fire blight control in organic pome fruit without antibiotics. *Plant Disease* 97:402–409.
17. K. Johnson, personal communication.
18. For example, Yoder, K.S. et al. 2013. Tests of copper for blossom blight and scab control and fruit russet effects on Gala apple, 2013. Research report, Virginia Tech Agr. Res. Ext. Center, Winchester, VA; and Smith, T. 2012. Improving the management of two critical pome fruit diseases. Research Report, WA Tree Fruit Research Commission. http://jenny.tfrec.wsu.edu/wtfrc/core.php?rout=displtxt&start=139&cid=529.
19. Tests in Virginia by K. Yoder showed that Regalia™ gave FB suppression equal to Serenade™, but it is unknown whether Regalia™ will have the same effect on reducing Blossom Protect™ yeast levels and thus reduce potential russet levels under extended wet conditions.
20. Johnson, K. et al. Evaluation of copper materials for suppression of apple fire blight, 2013. Research trial report, Oregon State Univ., Corvallis, OR.
21. Based on grower experience with lime sulfur [lime sulfur-fish oil] and Serenade Max™ ; and Dr. K. Johnson, unpublished data for 2010–2013, preliminary results of test trials on Blossom Protect™, lime sulfur, and soluble copper.
22. An initial test in Virginia did find greater russet with Cueva than the non-treated control or antibiotics, but similar levels to other copper materials. Interestingly, in another test, Cueva plus Double Nickel led to less shoot blight and less russet than

Cueva alone, illustrating how much there is to learn about new materials and their combination with other old and new materials. Caution: this initial test involved other fungicides not applied to the control which may have affected the true russet contribution of the copper products.

23. Based on preliminary data from 2013 trial on 'Gala' apple, Dr. K. Johnson.
24. From experience, during the stages up to tight cluster, high water volume with high spray material concentration is best for both apples and pears. Post tight cluster, volumes and spray concentrations have to be adjusted according to the cultivar susceptibility to russet.
25. There may be restrictions in some states on this use. For example, lime sulfur is restricted in CA for use on d'Anjou, Seckel, and Comice if green tissue is present.
26. Pyrethrum and lime sulfur and oil will have some effect on reducing populations of early emerging predatory insects such as Brown Lacewing, Pirate Bugs, and *Deraeocoris* species (see Horton, D. 2004. Phenology of emergence from artificial overwintering shelters by some predatory arthropods common in pear orchards of the Pacific Northwest. J. Entoml Soc. Brit. Columbia 101:101–108). Grower experience indicates that suppression of adult pyslla egg laying (with pyrethurms), and destruction of the emerging pyslla egg hatch (with lime sulfur/oil) provides the best option for early pyslla control and sets the stage for effective psylla control by predatory insects post bloom and during the summer (especially with releases of predatory insects). In CA, a dormant oil treatment (with or without sulfur) is normally applied, followed by a lighter delayed dormant treatment approximately 4 weeks later (in recent years with copper added). This treatment can be delayed somewhat into green tissue presence (but without the copper) if there is no expectation of using sulfur pre-bloom for rust mite or scab control (B. Zoller, personal communication).
27. Counts of 10 or more adult psylla per tray sample (average) is the pyrethrum spray action number. Tray counts of adult psylla normally drop for 2–3 days post spray. Repeat the spray program again at 10 adults per beat tray (average) up until first white stage or until the introduction of predator insects.
28. If no organic soluble copper is approved for the region, wettable sulfur is an option with a pyrethrum spray for adult pyslla suppression at tight cluster timing. After this last pyrethrum spray, psylla control needs to focus on the introduction and buildup of predatory insects. This action is required because there is typically a 4-week window starting at this stage where psylla populations increase at faster rates than the buildup of local predatory insects and otherwise leave a period before new predatory larvae take control.
29. In California there may continue to be rust mite control with sulfur as long as projected oil use for spider mite suppression is still at least 1 month distant (B. Zoller, personal communication).
30. BloomTime™ would be a good choice at this timing, but there is currently a potential problem with the new manufacturer being undecided about the future production of this product. If this material is not available, start early with Blossom Protect™. If wet conditions persist during this window consider a soluble copper program to protect from FB. If soluble copper is not approved, consider SerenadeMAX™. If scab is an issue, copper is probably the best choice.
31. An example of research on this strategy can be found in Zoller, B.G. 1997. Preharvest release of green lacewing eggs and adults to suppress levels of overwintering adult pear psylla. Proc. WOPDMC 71:43–44. http://entomology.tfrec.wsu.edu/wopdmc/1997PDF/3-Biocontrol/Biocontrol%2097-7.pdf
32. Growers can go online and order large quantities of 'egg cards' for overnight delivery (not possible a few years ago). The cards are cut into small squares with a razor blade, placed between a square of newspaper and stapled. The next day, using a hammer stapler, the egg cards are distributed rapidly (usually with an ATV) to a protective position in the pear tree under the newspaper strip. Paper coffee cups with lids work well also and protect the newly hatched lacewing larvae from the environment.
33. Lacewing adult predator insects can be attracted in large numbers into the orchard block by placing inexpensive solar powered walkway lights on poles that extend slight above tree canopies. Also, by adding paper coffee cups containing an absorbent material impregnated with organic wintergreen oil to the light poles, additional lacewing populations will be lured into the block.
34. From Dr. K. Johnson, unpublished preliminary data. Serenade Optimum™ sprayed after Blossom Protect™ caused about a 40% decline in the yeast population.
35. K. Yoder, personal communication.
36. Auvil, T. 2010. Planting for the future: rootstocks. Good Fruit Grower, Jan. 15, 2010. http://www.goodfruit.com/Good-Fruit-Grower/January-15th-2010/Planting-for-the-future-Rootstocks/
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Research Results

California Pear Advisory Board http://www.calpear.com/industry/research-reports.aspx

Washington Tree Fruit Research Commission http://www.treefruitresearch.com/resources-downloads/searchable-database.html

USDA-ARS, Kearneysville, WV http://www.ars.usda.gov/pandp/people/people.htm?personid=22417

New York State Horticultural Society http://www.nyshs.org/fq.php

Some U.S Research Programs Working on Fire Blight

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Washington State University, Prof. Tim Smith,

University of California, Dr. Jim Adasdaveg, Dr. D. Gubler, Dr. Rachel Elkins

Michigan State University, Dr. George Sundin

Cornell University, Dr. Herb Aldwinckle, Dr. Kerik Cox

Virginia Tech, Dr. Keith Yoder

USDA-ARS, Dr. Jay Norelli, Dr. Gennaro Fazio

Photos

Photos courtesy of Dr. Jay Norelli, USDA-ARS, Kearneysville, WV

Cankers on the bark leak a bacterial ooze which contains the pathogen and is picked up and spread by insects.

Infected blossoms already showing symptoms.

Classic symptoms of fire blight infection of new shoots.

An infected fruitlet exhibits bacterial ooze.

The fire blight bacteria can travel down to the rootstock, infect it, and kill the tree.

A young orchard with extensive fire blight infection.

Appendix 1. Selecting Cultivars with Greater Fire Blight Resistance

Fire blight resistance

No domesticated apples or pears appear to be immune to infection by the fire blight bacteria. Different germplasm has different degrees of resistance to the disease, and susceptibility typically lessens with age. For resistance, think about two cultivars in the same environment, where they are equally exposed to the disease. Cultivar A shows less disease than cultivar B, and would be considered more resistant. These differences exist on a continuum, and often a description of resistance is divided into categories: e.g., highly susceptible, moderately susceptible, moderately resistant, resistant, highly resistant, (immune). Once a tree is infected, greater genetic resistance leads to less spread of the disease in the tree and less damage. As a rule, the older the tree, the more resistant it is to fire blight damage, and older wood on a tree is more resistant than young wood on the same tree. Different plant parts show varying susceptibility. For example, flowers of 'Red Delicious' are very susceptible, but the young wood is not; thus, bacteria entering through the flower do not spread very far down the branch and damage is limited. 'Red Delicious' has the greatest level of resistance of all apple cultivars in wide commercial use, but can still suffer 45–65% infection of blossoms if untreated. Unfortunately, market demand over the past 15 years has shown that organic consumers have a relatively low preference for fruit from this cultivar.

Some apple breeding programs have simply screened for enhanced fire blight resistance in crosses, while others have deliberately tried to select for this trait (Lespinasse and Aldwinkle, 2000). The PRI apple breeding program http://www.hort.purdue.edu/newcrop/pri/default.html from the Midwest has released a number of cultivars with purported improved fire blight tolerance. Examples are 'Pristine', 'Williams Pride', 'Priscilla', and 'Juliet.' The apple breeding program at Dresden-Pilnitz, Germany, has produced several selections in the 'Re' series with enhanced resistance to fire blight and putative commercially acceptable fruit quality. These breeding efforts have typically relied on crosses with crab apple for the fire blight resistance which generally brings in other traits that lead to unacceptable fruit quality.

Apples and pears are grown as grafted trees, so the resistance of both the scion (fruiting top-part of the tree) and rootstock must be considered. Over the past several decades, commercial apple growers have transitioned to dwarfing rootstocks that increase productivity and fruit quality, as well as general pest and disease control efficacy (critical for organic). However, trees on dwarfing rootstocks flower at an earlier age (when the tree is more susceptible) and tend to have more secondary and tertiary bloom (which occur later in the spring when there is increased infection risk). The most widely planted dwarfing apple rootstock is the Malling series 'M.9', which is highly susceptible to fire blight. The new 'Geneva' rootstock series has a greater level of fire blight resistance than the Malling or Malling-Merton series, and desirable horticultural qualities, but trees are not yet widely available from nurseries, who estimate a 3–4 year time frame to be able to fulfill the demand. Additionally, the resistant rootstock does not confer resistance to infection or damage in the scion part of the tree, although there is some initial evidence to suggest some improvement in resistance in the scion. The practical benefit of rootstock resistance is that an infected scion is less likely to kill the entire tree. The B.9 rootstock showed high susceptibility when grown as an own-rooted tree but suffered zero mortality when it was the rootstock with several different scions (Russo et al., 2008). Growers have reported similar experience with this rootstock.

Pears show less variation in resistance and are generally more susceptible than apples. Over 90% of pear cultivars are susceptible to fire blight, while there are only 5 or 6 cultivars with wide commercial acceptance. Many pear orchards are decades old and these large trees may become infected but are less likely to die than young trees. 'Bosc' pear is particularly susceptible to fire blight, and even older trees can be killed. 'Seckel' pear, a small-fruited cultivar that is commercially produced, is quite resistant to fire blight and is a source of resistance in some breeding programs. A Canadian breeding program has developed the 'Harrow' series of pears which all have improved resistance to fire blight as compared to 'Bartlett' pears, but none are totally immune. These include 'Harrow Swee't, 'AC Harrow Crisp', 'AC Harrow Gold', 'Harvest Queen', and 'Harovin Sundown'. The USDA pear breeding program has also developed a number of cultivars with improved resistance. These include 'Magness', 'Moonglow', 'Dawn', 'Potomac', 'Blake's Pride', 'Shenandoah', and 'Sunrise'. A fact sheet on some of these cultivars is available (Bell, undated). Trees from these programs are being evaluated in several contrasting locations in the U.S. and Canada. Many of the "blight resistant" cultivars that have been developed by various pear breeding programs around the world have not been popular with growers or consumers for various reasons, and thus the search for more acceptable fire blight "resistant" cultivars continues.

Listings of resistant cultivars

A number of resources are available that list apple and pear cultivars that are reported as more or less fire blight resistant. The degree of resistance, particularly in comparison to a known cultivar, is generally not presented, making it difficult for a grower to determine the real utility of selecting these varieties for that specific trait. These ratings tend to be compilations from different sources that did not necessarily use the same methodology for assessing resistance and exhibit some variability in their rating for the same cultivar. They may also have used different strains of the fire blight bacterium to induce infection, which can alter the results. For example, Purdue University lists 'Winesap' apple as highly resistant, while West Virginia University lists it as susceptible, and Colorado State University lists it as moderately resistant. However, these lists do typically state that none of the listed cultivars is immune and all will become infected under high-risk conditions. Some smaller nurseries also offer lists of cultivars with specific disease resistance (for example, Cummins Nursery, http://www.cumminsnursery.com/disease.htm) that can be useful for getting a few trees to test. However, given the multi-year nature of this testing, this is not a short-term solution for growers, and these nurseries generally cannot provide enough volume of a given tree to meet the needs of commercial-scale growers.

Results of fire blight screening of more contemporary apple varieties done in the field in New York State using cut leaf inoculation are presented in Table 1. The lowest percent lesion is desired. 'Red Delicious' is a good standard for comparison. 'Honeycrisp' is similar to 'Red Delicious'. 'NevisSonya' showed no infection, as did the rootstocks G.41 and Robusta 5.

Table 1. Field screening of contemporary apple cultivars for fire blight susceptibility. Trees infected via cut leaf inoculation. Ranges express means from two fire blight strains Ea273 and Ea4001a. Maximum lesion of zero represents the greatest resistance. Unpublished data from G. Fazio, H. Aldwinckle, and J. Norelli.

Cultivar	Mean Percent Lesion	Maximum Percent Lesion
Scions		
Ambrosia	6–12	41–50
Red Delicious	4–10	18–22
Empire	0–6	0–12
Gala	4–30	11–37
GoldenDelicious	22–30	45–100
GoldRush	8–17	30–41
HoneyCrisp	5–8	22–29
Jazz	15–36	39–51
NevisSonya	0	0
PacificRose	14–15	27–36
Pinova	16–25	31–42

Cultivar	Mean Percent Lesion	Maximum Percent Lesion
Pinova	16–25	31–42
Sundance	11	22–24
SweeTango	13	13
Topaz	16	23
WSU2	24	53–54
WSU38	11	13
Zestar	3–22	8–31
Rootstocks		
G.41	0	0
M.27 EMLA	19–28	44–58
M.9 EMLA	6–42	50–100
Robusta 5	0	0

Tables 2–4 present compilations of qualitative fire blight ratings from three different university publications. A limited number of cultivars are included by all three, and their rating categories are not identical. For apples, 'Empire' generally receives a rating showing some level of resistance (Table 2), which corresponds to its rating in Table 1. 'Red Delicious' is similar and is the only cultivar rated Resistant by Colorado State. Other cultivars with more than one rating suggesting some resistance include 'Arkansas Black', 'Goldrush', 'Haralson', 'Jamba', 'Jonafree', 'Liberty', 'Melba', 'Melrose', 'Nova Easygro', 'Priscilla', 'Stark Bounty', 'Turley', and 'Wellington'. For pear, the widely planted cultivars of 'Barlett' and 'd'Anjou' are both quite susceptible (Table 3). Several new cultivars such as 'Magness' and 'Moonglow' are rated for higher levels of resistance. Similar ratings of some common rootstocks are provided in Table 4. However, a higher resistance rating alone is seldom sufficient for determining whether a cultivar will be suitable, especially for commercial production. Many other factors must be considered, including other diseases and pests, horticultural issues, storability, harvest timing, consumer preference, and more.

Table 2. Fire blight susceptibility ratings for apples from different university sources.

MR = moderately resistant
S = susceptible
HS = highly susceptible

Apple cultivar	WVU^z	Purdue	CSU
Akane			MR
Arkansas Black	MR		MR
Baldwin	S		HS–MS
Barry	HS		HS
Beacon	S	S	HS–MS
Belle de Boskoop			MS
Blushing Golden			MS
Ben Davis	HS		HS
Binet Rouge			HS
Black Twig			HS
Braeburn	HS		HS
Brown Snout			HS
Britemac	MR		MR
Burgundy	HS		HS
Carroll	MR		MR
Chisel Jersey			HS
Classic Delicious			MR
Cortland	S	S	HS–MS
Cox's Orange Pippin			MR
Dabinette			HS
Delbarestival			MS
Gala	HS	S	HS–MS
Royal Gala			HS–MS
Fulford Gala			MS
Stark Gala			MS
Imperial Gala			MS
Scarlet Gala			MR

Apple Cultivar	WVU^z	Purdue	CSU
Stark Splendor	MR		MR
Starkspur Earliblaze	S		MS
Starr	HS		HS–MS
Staybrite			MS
Stayman	S		MR
Stembridge Jersey			HS
Stokes Red			HS
Summer Rambo	S		HS
Summerred	S		MS
Summer Treat			MS
Super Jon			HS
Swiss Gormet (Arlet)			MR
Topaz			MS
Tremletts Bitter			HS
Turley	MR		MR
Twenty Ounce	HS		HS
Tydeman's Red			MS
Ultra Red			HS
Delicious	MR		
Discovery			MS
Durello di Forli			HS
Dutchess		R	MS
Earli Jon			HS
Earligold	S		HS–MS
Early McIntosh	MR		MS-MR
Early Red One McIntosh			MR
Early Spur Rome			HS

(Continued on next page)

(Table 2 continued)

Apple cultivar	WVU[z]	Purdue	CSU
Geneva Early			HS
Ginger Gold	HS		HS
Gloster	S		MS
Gloster 69			HS
Golden Delicious	S	S	HS–MS
Golden More Super			HS
Golden Russet			HS
Goldrush		R	MR
Gold Spur			MR
Granny Smith	HS	S	HS–MS
Grimes Golden	S		MS
Gravenstein Holly	S		MS
Haralson		R	MR
Hared		S	
Hereford Redstreak			HS
Honeycrisp		R	
Honeygold		S	MR
Idared	HS		HS
Jamba	MR		MR
James Grieve			MR
Jerseymac	S		MS
Jonafree		HR	MR
Jonagold	HS	R	HS–MS
Jonamac	S	R	MS–MR
Jonathan	HS	S	HS
Jonnee			HS
Julyred	S		MS
Keepsake			MR
Kidd's Orange Red			MR
Kingston Black			HS
Late Harrison			HS
Liberty	MR	R	MS–MR
Lodi	HS	S	HS
Lurared			MR
Lustre Elstar			MR
Lysgolden			MR
Macfree			MR
Macoun	S		MS
Macspur			MR
Maiden Blush	S		MS

Apple Cultivar	WVU[z]	Purdue	CSU
Ellis Bitter			HS
Elstar			HS–MS
Elstar Red			MS
Empire	MR	R	MS–MR
Enterprise			MS–MR
Florinia			MS
Freedom			MS–MR
Fuji	HS	S	HS
Fuji, Red			MS
Fuji, Red Nagano			HS
Medaille d'Or			HS
Melba	MR		MR
Melrose		HR	MR
Milton	S		MS
Milwa			HS
Minyon			MS
Missouri Pippon			MS
Mollies Delicious	S		MS
Monroe	S	S	HS–MS
Mor Spur Mac			MR
Mutsu (Crispin)	HS	S	HS–MS
Niagara	HS		HS
Nicobel Jonagold			HS
Nittany	HS		HS
Northern Spy	S	R	MS–MR
Northwestern Greening	MR	HR	HS-MR
Nova Easygro		HR	MR
Novamac		R	MS
Nured Delicious			MR
Nured Jon			HS
Nured Winesap			MR
Otava			HS
Ozark Gold			MR
Paulared	HS	S	HS
Perfect Spur Criterion			MR
Pink Lady			HS
Pinova			MS
Pioneer Mac			MR
Porter's Perfection			HS
Prima		HR	MS–MR

(Continued on next page)

(Table 2 continued)

Apple cultivar	WVU[z]	Purdue	CSU
Margil			HS
McIntosh	S	R	MS
Red Max			MR
Red Winesap			MR
Red Yorking	HS		HS
Regent			MR
Reglindis			HS
Reine de Hatives			HS
Reine des Reinettes			HS
Reinette Grise du			MS
Remo			MR
Rhode Island Greening	HS		HS
Roberts crab			HS
Rome			HS
Rome Beauty	HS	S	HS
Rome, Starkspur Law			HS
Rubinette			MS
Rubinola			MR
Sampion			HS
Santana			HS
Scotia	S		MS
Sharon			MS
Sir Prize		HR	HS-MR
Smoothee			MS–MR
Somerset Redstreak			HS
Sops of Wine			HS
Spartan	S	R	MS
Spigold	HS		HS
Spijon	S		MS
Stamared			MR
Stark Bounty	MR		MR

Apple Cultivar	WVU[z]	Purdue	CSU
Priscilla	MR	HR	MR
Puritan	S		MS
Quinte	S	HR	MS–MR
Ramey York			HS
Raritan	HS		HS
Redfree	S	HR	MS–MR
Reanda			MR
Red Delicious			R
Red Delicious, Starkspur, Starking, Starkrimson, Scarlet Spur, Sturdeespur, Topspur, Dixi, Dana, Ace, Red Chief			MR
Red Delicious, Super Chief			MS
Viking	MR		
Virginiagold			MS
Wayne	S	S	HS–MS
Wealthy	S	S	MS
Wellington	MR		MR
White Jersey			HS
Williams Pride			MR
Williams Red			MR
Winesap	S	HR	MS–MR
Yellow Transparent	HS	S	HS
York Imperial	HS		HS
Zestar		S	

Table 3. Fire blight susceptibility ratings for pears from different university sources.

Pear cultivar	WVU	Purdue	CSU
Abbe Fete			HS
d'Anjou	S	S	MS
Aurora		S	HS
Ayers			MR
Bartlett	HS	S	HS–MS
Beurre Bosc			MR
Bosc		S	HS
Bradford			MR
Carrick			MR
Clapp's Favorite	HS	S	HS
Comice	S	S	HS–MS
Conference			HS
Coscia			MS
Dawn			MS
Douglas	S		MS
Duchess	S	S	MS
Ewart	S		MS
Flemish Beauty	HS		HS
Flordahome			HS
Garber	S		MS
Gorham	HS		HS
Hardenpont			HS
Hardy	HS		HS
Harrow Delight			MR
Harrow Sweet			MR

Pear cultivar	WVU	Purdue	CSU
Harvest Queen			MS–MR
Honeysweet		HR	MR
Hood			HS
Kieffer	MR	HR	MS–MR
LeConte	MR	HR	MR
Lincoln	S		MS–MR
Luscious			MS–MR
Magness	MR	HR	MR
Maxine	MR	R	
Moon Glow	MR	HR	
Old Home		HR	
Oliver de serres			HS
Passe Crassane			HS
Red Bartlett			HS
Reimer Red			HS
Seckel	S	R	
Sheldon	HS		HS
Spaulding			HS
Starkrimson			HS
Tyson	MR		MR
Waite	MR		MR
Warren			MR
Williams			HS
Winter Nelis	HS		HS

The basis for the ratings in Tables 2 and 3 is as follows:

1. West Virginia University http://www.caf.wvu.edu/kearneysville/tables/fbsus.html

   MR = Moderately resistant. Control only needed with fire blight susceptible rootstocks or under high disease pressure.
   S = susceptible. Control usually needed when conditions are favorable for infection.

   HS = highly susceptible. Control always needed when conditions are favorable for infection. These cultivars should receive first priority when control is called for.

2. Purdue University, Purdue Extension BP-30-W, http://www.extension.purdue.edu/extmedia/BP/BP-30-W.pdf. Scale of highly resistant (HR), resistant (R), and susceptible (S). A more refined rating is provided by Beckerman (2006).

3. CSU= Colorado State University. Extension fact sheet 2.901, Fire blight; http://www.ext.colostate.edu/pubs/garden/02907.html . Scale of highly susceptible (HS), moderately susceptible (MS), and moderately resistant (MR)

Table 4. Apple and pear rootstock fire blight susceptibility.

	Highly susceptible	Moderately susceptible	Moderately resistant
Apple	Alnarp	Malling 7 EMLA	Bemali
	Malling 9	Budagovsky 9	Budagovsky 118
	Malling 26	Vineland 3	Budagovsky 490
	Malling 27	Geneva 16	Geneva series
	Mark Series		Malling 7
	Ottawa		Robusta
	Poland 2		Vineland 1
	Poland 16		Vineland 2
	Poland 22		Vineland 5
	Vineyard 4		Vineland 6
			Vineland 7
Pear	Provence quince (*Cydonia obonga*)		*Pyrus betulaefolia* 'Old Home x Farmingdale'
	Pyrus communis 'Bartlett'		*Pyrus calleryana*
	Pyrus communis 'Winter Nelis'		*Pyrus communis* 'Old Home'
			Pyrus communis 'Old Home X Farmingdale'

Source: Colorado State University, Extension fact sheet 2.901, Fire blight; http://www.ext.colostate.edu/pubs/garden/02907.html Scale of highly susceptible (HS), moderately susceptible (MS), and moderately resistant (MR)

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