

Maryblyt™ 7.1 (for Windows)

A Predictive Program for Forecasting Fire Blight Disease in Apples and Pears

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The program is available for free by downloading from:

<http://www.caf.wvu.edu/kearneysville/Maryblyt/index.html>

We request that you do not redistribute it.

Truth is a perception of reality that is consistent with all relevant facts and is refuted by none
... J.G. Horsfall and E.B. Cowling, 1978

Acknowledgements (by Paul W. Steiner, from the original release of *Maryblyt*[™])

From the inception of *Maryblyt*[™] in 1986, the authors have benefited from collaborations with many research and extension workers, fruit growers and private crop consultants. For some, like Rick Heflebower, Western Maryland Extension Fruit Specialist, it was a commitment of time and energy in detailed data collection and the development of the first area forecast system using the program. For fruit growers, like Bruce Barr, William Gardenhour and the late George Gardenhour, it was the generous commitment of valuable commercial orchards to sometimes risky research. Throughout the development of *Maryblyt*[™], the authors have benefited from the contribution of data, in-depth discussions, and intellectual challenges by members of the Appalachian Fire Blight Consortium, an informal association of colleagues in the mid-Atlantic region who have met regularly several times each year since 1983. Along with the author, that group includes: A.R. Biggs and J.G. Barrat (ret.) , West Virginia University; K.D. Hickey (ret.), Pennsylvania State University; K.S. Yoder, Virginia Polytechnic Institute and State University; and T. Van Der Zwet (ret.), USDA\ARS Appalachian Fruit research Station, West Virginia.

Many others contributed detailed orchard data, helped validate the model and provided constructive criticism in the continuing development of *Maryblyt*[™]. These efforts broadened our database and led to a number of significant changes incorporated into this version. We wish to gratefully acknowledge the cooperation of: W.G. Bonn, Agriculture Canada, Ontario; D.R. Cooley, University of Massachusetts; C.E. Doll, Illinois Coop. Extension Service; M.A. Ellis, Ohio State University, OARDC; M. Gleason, Iowa State University; G.G. Grove, R. Boal and E. Beers, Washington State University; G. Clarke and L. Hull, Pennsylvania State University; A.L. Jones, Michigan State University; R.W. Miller and E. Zehr, Clemson University; P.G. Psallidas, Phytopathological Inst., Athens, Greece; S.M. Ries, Illinois State University; D. Rosenberger, Cornell University; W.H. Shaffer, JR., University of Missouri; P. Sobiczewski, Pomology & Floriculture Inst., Skierniewice, Poland; R. Spitko, New England Fruit Consultants, MA; R.A. Spotts, Oregon State University; P. Suleman, University of Maryland; T.B. Sutton, North Carolina State University; S.V. Thomson, Utah State University; J. Travis, Pennsylvania State University; M. Willett and T. Smith, Washington State Coop. Extension Service; and, B. Zoller, The Pear Doctor, CA.

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Maryblyt™

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General introduction to version 7.1

(Adapted from the original introduction to version 4.3 by P. W. Steiner and G. W. Lightner)

Few plant diseases are more destructive or more difficult to control than fire blight on apples and pears. It is caused by a bacterium, *Erwinia amylovora*, and can kill blossoms, vegetative shoots, limbs, and whole trees. Good control is costly and difficult because epidemics occur sporadically and because our options for control lie mostly in cultural practices and the limited use of antibiotics. In addition, fire blight epidemics often develop in several phases, each requiring different control measures and not all phases occur every year. Our best control programs rely on protective measures, which must be taken *before* infections occur. However, without a reliable method for predicting when infections are likely, it is difficult to develop a cost-effective control program that works consistently.

THE *Maryblyt*[™] PROGRAM

Maryblyt[™] is a comprehensive computer program for predicting specific infection events and symptom development for most phases of fire blight epidemics in apples and pears. The first version was developed in 1988 at the University of Maryland and was based on published research reports and observations on the occurrence of blight in Maryland apple orchards. Subsequent testing at over 20 locations in the northeast, southeast, Midwest and Pacific Northwest regions of the U.S. and in Canada from 1989 to 1991 led to many improvements that allow broad application of the program for apples and pears in different climates.

Maryblyt[™] has been the principal basis for recommendations to Maryland fruit growers on fire blight control since 1989. Its use has resulted in a marked improvement in the level of control obtained and a reduction in the number of antibiotic sprays applied compared with more conventional approaches. It can also be used to signal when symptoms can be found and removed, or when other control measures may be appropriate.

One unique feature of *Maryblyt*[™] is that it identifies and predicts not only specific infection events, but also predicts the appearance of four distinct types of fire blight symptoms: blossom, canker, shoot and trauma blight. The program can be operated in real time to assess the current risks or progress of an epidemic, and in a simulation mode for predicting future events using forecast weather. Information generated in both modes provides a basis for making decisions on when to make specific control treatments and when it is reasonably "safe" to delay those treatments.

VERSION 7.0

Maryblyt[™] Version 7.0 includes several changes from earlier versions that improve ease of operation and which clarify decision-making. Unlike Version 4.3, files in Version 7.0 are initialized specifically for apples or pears in the Season Properties dialog box at the beginning of the season. However, this can be changed back and forth between apples and pears with minor changes so a single file can be used for predictions in both crops. This difference is based on differences between the two crops in the time their respective flowers are susceptible and subject to colonization. As such, the risks for infection are conservatively

based on the oldest open (i.e., susceptible) flower in the orchard. Version 7.0 also differs from previous versions in that, with the application of a blossom protective spray, the epiphytic infection potential (EIP) is reset to zero. This means that the risk potential for flowers opening after that application is reestablished as a function of colonization by the bacteria. In previous versions, the EIP remained unchanged and the program used an arbitrary 3-day "safe" interval before warnings reappeared. This change is expected to be more realistic in that the "safe" interval following flower treatments now varies in response to prevailing weather conditions. However, this change disabled the ability to track infections in the BBS column that were controlled by a spray, thus limiting the ability of the user to determine spray efficacy without keeping two separate data sets (i.e. one labeled Management and the other No Management) to track BBS following an infection event where a spray was applied. We will try to address this issue in any future updates. Finally, all model parameters are editable to allow advanced users to modify model performance to adjust for factors not accounted for in the current model, such as varietal resistance and geography. In previous versions, only a limited number of parameters could be changed.

Maryblyt™ 7.1 incorporates several cosmetic and functional changes, including: capability to utilize international units, a spray effectiveness module that allows users to enter a spray efficacy threshold to account for treatments that are less than 100% effective (default value set to 100%), the ability to turn on and off the effect that spraying antibiotic has on EIP and subsequent blossom blight symptoms (BBS) so that users can track symptom development as if they had not sprayed so that BBS can be monitored more effectively and spray effectiveness can be evaluated, and, finally, we've re-established the audible warning to alert users when an infection event has occurred and provided a switch to turn it on and off.

DATA INPUTS REQUIRED

Daily information on temperature, rainfall and other weather events along with key observations on apple or pear bud development are needed to use **Maryblyt™**. The program is most accurate when operated using on-site weather and bud development data. Data collected at locations distant from the orchard site can provide general area forecasts, but they may lack precision in forecasting some events in individual orchards. Where data gaps occur due to missed or faulty weather instrument readings, some predictions may be missed or delayed so that the timing of treatments is less inaccurate. Users are strongly advised to invest in a reliable recording weather station. If weather instruments must be reset manually on a daily basis (e.g., a minimum-maximum thermometer), data collection should be done at regular intervals.

All weather data can be entered or retrieved in either U.S. or metric units. The specific weather information needed includes: daily minimum and maximum temperatures, rainfall amounts (0.01 inch, 0.25 mm) and leaf wetness events that occur as the result of dew or heavy fog. Predictions for trauma blight events are automatically triggered by the temperature data for late frosts, but hail and high wind events that damage the foliage must be entered when they occur.

Since the **Maryblyt™** model is based on host tree development; the program must be "informed" of these changes at three times: 50% green tip, first open bloom and petal fall. Each of these entries signals the program to begin or to stop certain functions. Errors in entering these "biofix" points can result in missed or delayed forecasts.

USING THIS MANUAL

The manual for Version 7.1 has been fully edited from previous versions. New information about fire blight has been added and some areas have been expanded to clarify aspects of the model or the program where users have raised questions. Despite the changes introduced with Version 7.1, every effort has been made to maintain the overall simplicity, accuracy and reliability that have been a characteristic of **Maryblyt™** since its first release.

This manual is arranged in three parts: I. *Understanding Fire Blight* provides the biological bases for the computer program; II. *Managing Fire Blight* focuses on risk assessment and the strategies and tactics for fire blight control; and III. **Maryblyt™** *Program Operation* contains the program operating instructions.

PART I. UNDERSTANDING FIRE BLIGHT: The Biological Bases for *Maryblyt*[™]

INTRODUCTION

Symptoms of fire blight were first described over 200 years ago and, until 1919, when it was reported from New Zealand, the disease was limited exclusively to North America [van der Zwet & Keil (1979)]. It now occurs in at least 27 countries worldwide on four continents. The long distance spread of the bacterial pathogen, *Erwinia amylovora*, into new areas occurs primarily via the movement of contaminated planting stock, major storms and prevailing winds. Throughout this history, once the pathogen becomes established in a new territory, efforts to eradicate it seem largely futile and problems with the disease persist. Nevertheless, where the disease is detected early and aggressive tactics are employed on a timely basis, it does appear that outbreaks can be contained and, with good management, severe losses can be reduced. Indeed, in our experience, even where fire blight is well established, an aggressive management program can reduce the risks for major losses.

Since its discovery, many aspects of fire blight have been defined, but only recently have we begun to discover some of the specific requirements governing the infection process and to understand how these affect the progress of epidemics. *Maryblyt*[™] [Biggs & Turechek (2010), Lightner & Steiner (1990), Steiner (1990a, b)] is an attempt to integrate much of what is now known about the disease in apples and pears into one comprehensive model. Our primary focus has been to construct a program that fruit growers can use as an aid in making decisions for controlling fire blight in apple and pear orchards. Because of its accuracy, *Maryblyt*[™] has also found use in research, teaching and extension programs. This section describes the biological bases for the *Maryblyt*[™] program so that the user can better interpret the forecasts it provides.

MULTIPLE PHASES OF FIRE BLIGHT

Fire blight epidemics develop in several phases, each of which can be identified by a distinctive set of symptoms. Recognizing these phases and understanding how each develops is important for assessing risks and for making decisions on the most appropriate control measures needed. There are at least five distinct kinds of infections associated with fire blight, not all of which occur every year or with equal intensity. The *Maryblyt*[™] program predicts four of these: blossom, canker, shoot and trauma blight. A fifth type, rootstock blight, has only recently been characterized and the bases for its prediction are not yet fully understood.

Blossom blight. Blossom blight symptoms result from direct infections of open flowers with intact petals. Early symptoms develop as a darkening of the flower base or petiole, which may be accompanied by tiny droplets of ooze. The infected petiole soon wilts and the pathogen invades the spur and other flowers in the cluster. In some cases, damage is limited to the fruiting spur, but the pathogen often continues to invade and kill a portion of the supporting limb or branch. Since blossom infections are usually the earliest to develop and occur in large numbers over a wide area, they are a major source of secondary inoculum

that can fuel later epidemics of shoot blight.

Canker blight. Canker blight symptoms develop as the result of renewed activity by the pathogen at the margins of overwintering cankers established during the previous season. Unlike other phases of the disease, canker blight occurs regularly every year in areas where the disease is established (Steiner 1990b). The earliest symptom of canker blight is the appearance of a narrow, water soaked zone in the healthy bark tissue bordering active cankers. This can be seen only by cutting through the bark across the canker margin. Within a few days after this, brownish streaks can be seen in the inner bark tissue. The bacteria then invade nearby vegetative shoots internally, causing them to wilt and die. Such shoots, especially water sprouts, are often mistaken for symptoms of early shoot blight.

Shoots infected via the internal or systemic invasion as part of the canker blight phase can be distinguished from shoot blight by the early yellow to orange discoloration of the tip bud just prior to wilting. In some cases, symptoms of canker blight may be atypical for the disease in that a limb may simply decline rapidly and die in the spring. This occurs when an overwintering canker becomes active in the spring and girdles a limb.

Shoot blight. Shoot blight symptoms result from direct infections of vegetative shoot tips [top or youngest 3 leaves are susceptible]. From this initial site of infection, the bacteria then invade and kill the entire shoot and, often, a portion of the supporting branch. The earliest symptom of shoot blight is tip wilt, which causes the tip to curve downward like a shepherd's crook.

Unlike the infected shoots associated with canker blight that are invaded from below, shoots infected via the tip leaves do not show early discoloration before wilting, but remain green until necrosis develops. Shoot blight that occurs late in the season, shortly before terminal bud set, may never show this characteristic wilt and the necrosis that follows often is limited to only the upper portion of the shoot's length. Shoot tip infections, which occur earlier in the season progress rapidly, killing the entire shoot, and frequently invade the supporting limb where a canker may develop. The occurrence of shoot blight usually follows the appearance of either blossom or canker blight symptoms in or around the orchard and appears to be related to the presence and activity of insects with sucking or piercing mouthparts.

Because most shoot infections occur after bloom, the physiological status of the tree at that time seems to allow infections to progress further so that more limb damage occurs than with other types of infections. Such late infections also tend to result in more overwintering cankers, which are then available the next season.

Trauma blight. Trauma blight symptoms develop on many different tissues and are associated with infections following injuries caused by late frosts, hailstorms or high winds that damage the foliage. These injuries appear to breach defense mechanisms that normally confer resistance in mature tissues of susceptible cultivars and in generally resistant cultivars like Red Delicious to fire blight [Suleman (1992)]. Similar effects may occur when cuts are made to remove infected branches during the growing season, which often result in the

formation of small cankers on the branch stubs [Suleman (1992)]. Such cankers provide additional sources of inoculum for continuing fire blight epidemics in subsequent years.

Rootstock blight. Rootstock blight occurs when bacteria from blossom or shoot infections (including trauma situations) move systemically into the rootstock and initiate a localized canker that girdles and kills the tree. It is especially prevalent with apple cultivars on the highly susceptible M.26, M.9 and Mark (Mac 39) rootstocks and C-6 interstems [Steiner (1991), Suleman (1992)]. It occurs most frequently when fire blight susceptible scion cultivars on these rootstocks become infected (blossom, shoot or trauma blight), but it can occur with resistant cultivars following a trauma blight incident (i.e., Red Delicious on the M.26 rootstock). The loss of > 30% of the trees in an orchard with susceptible scions on M.26 rootstocks within 5 to 7 years after planting is not at all unusual. While resistant scions like Red Delicious on these rootstocks are generally more durable, high tree losses can still occur following incidents of hail or high wind (i.e., trauma blight).

Rootstock blight develops as a canker just below the graft union, which eventually girdles and kills the tree. These infections are unusual in that the intervening scion trunk and limbs above the graft union and below the visible blight symptoms on the scion remain symptomless. Rootstock cankers can appear as early as mid-summer, but may not be detected until late summer to early fall, often inducing early red foliage in the fall. Some trees with rootstock cankers may not be clearly apparent until they decline in the spring of the season following the infection year. Since the scion trunk appears healthy and the symptoms of general decline and early fall red color in the foliage are not usually associated with fire blight, this phase of the disease often is mistaken for another common root disorder called collar rot, which is caused by the fungus *Phytophthora cactorum*. Rootstock blight is not predicted by *Maryblyt*[™].

HOW EPIDEMICS DEVELOP

Epidemics of plant disease result from the interaction between a population of susceptible host plants, a population of a pathogen, and favorable weather conditions. Fire blight epidemics can begin with a few early infections caused by inoculum that has overwintered in association with the crop. As these primary infections develop, they produce abundant inoculum, which is then available for dispersal to other infection sites. This process is repeated through many secondary cycles until either the supply of inoculum is exhausted or suitable infection sites (e.g., open blossoms or growing shoot tips) are no longer available. The cyclic nature of disease progress, with more inoculum being available following each infection, contributes to an exponential increase in the amount of disease, even where the amount of overwintering inoculum is low or when only a few scattered blossom infections occur. Fire blight epidemics can also appear as explosive events in which a single infection event occurring over a period of minutes to hours can result in hundreds of thousands of individual infections, each of which produces more bacteria that can initiate secondary infections.

The amount of disease that develops in any given season or orchard of susceptible cultivars will depend on: (a) the number and distribution of sources from which inoculum is

available; (b) the inherent genetic susceptibility of scion and rootstock cultivars; and (c) the rate at which new infections occur. The availability of primary sources is related to the amount of fire blight that occurred in and around the orchard in the previous year and the thoroughness of grower sanitation practices. The importance of the second factor, cultivar susceptibility, can be compounded by grower management practices that either reduce or increase this susceptibility (e.g., prolonged secondary flowering, excessive nitrogen fertilization). The apparent rate at which new infections occur is affected primarily by prevailing weather conditions (temperature, wind, rain) and the control measures taken by growers to protect blossoms and keep potential insect vector populations low.

Because the fire blight pathogen overwinters in established infections (= cankers) on the trees, reducing the number and distribution of these sources can be very effective in slowing the start of an epidemic. Other treatments such as early copper sprays to inhibit the pre-bloom colonization of plant surfaces and protective blossom sprays are also necessary to reduce the number of new infections that develop. It is important to understand, however, that since infections can occur within minutes under the right conditions, all such management efforts must be very well timed to occur *before* infections occur.

MONITORING AND PREDICTING FIRE BLIGHT

Plants and plant pathogens have little use for clocks and calendars; these are the inventions of man. The rates of growth and development in plants and pathogens and the progress of interactions between them (=disease) are controlled largely by environmental factors of which temperature is very important. Biological life is governed by many hundreds of processes all of which function best at some optimum temperature and less so, or not at all, below some minimum level or above some maximum level. A physiological or biochemical process or series of processes (i.e., symptom development) needs a certain amount of energy (as heat) for completion and is often independent from the rate at which that energy is supplied. Thus, the completion of processes like blossoming, bacterial colonization, insect development and symptom development can be monitored indirectly over time using cumulative heat units. Cumulative heat units are most commonly expressed as *degree days* (DD) or *degree hours* (DH) between minimum and maximum temperature thresholds.

One degree day represents the energy contributed by an average ambient temperature of one degree above an identified minimum threshold temperature below which a given process either stops or is severely inhibited. One degree hour is similar, but represents a shorter time frame for monitoring processes that are particularly rapid (i.e., bacterial multiplication and flower colonization).

Maryblyt™ integrates the use of three cumulative heat unit "clocks" to indirectly monitor the development of the host, pathogen populations, insect vector availability and symptom development. The age of apple and pear flowers and the appearance of insect vectors (Steiner 1990b), for example, can be monitored with reasonable accuracy using cumulative DD > 40 °F (4.4 °C) (see Fig. 1). Cumulative DH > 65 °F (18.3 °C) is used in **Maryblyt™** to establish the epiphytic infection potential (=EIP) for assessing infection risks (Steiner 1990a). The EIP is based on data relating cumulative heat units and blossom

colonization by the bacteria (Zoller & Sisevich 1979), but it really encompasses much more (availability of open flowers, bee activity, etc.). Thus, *an EIP of "zero" does not mean that all bacteria are dead, but only that the risk for infection is low*. Once infection occurs, symptom development (=interaction between a pathogen and a host plant) is predicted using cumulative DD > 55 °F (12.7 °C).

The degree days accrued in one day can be estimated by subtracting the base, or minimum threshold temperature from the daily average temperature. This approach was used in earlier **Maryblyt™** versions, but sometimes led to prediction errors in some climates, especially where there were wide differences between the daily minimum and maximum temperatures (e.g., the semi-arid US Pacific Northwest). Version 4.2 introduced the use of a mathematical sine wave function with a 90 °F (32 °C) maximum and various minimum temperature thresholds for DD and DH determinations that reduces some of this variability (Baskerville & Emin 1969). That approach is continued in Version 7.1 with an option for calculating DD and DH with a single or double sine wave function (Allen 1976). (Explanations and definitions for these terms can be found [here](http://www.ipm.ucdavis.edu/WEATHER/ddeval.html): <http://www.ipm.ucdavis.edu/WEATHER/ddeval.html> and [here](http://www.ipm.ucdavis.edu/WEATHER/ddfigindex.html): <http://www.ipm.ucdavis.edu/WEATHER/ddfigindex.html>).

Early dispersal of the pathogen. The fire blight pathogen overwinters in cankers on branches infected the previous season. Some of these cankers are large and can be easily identified on main limbs or tree trunks. Many others are located on small branches and around wounds where active infections were cut out during the previous growing season. *These latter cankers are difficult to find and can contribute to the amount of inoculum available the next season if not removed properly* (see Part II on cutting out infections).

During the pre-bloom period, warm temperatures, moisture and physiological changes associated with early bud development induce the bacteria to multiply rapidly (Suleman 1992). A thick, sticky ooze containing the bacteria is then exuded onto bark surfaces around cankers. Many different species of insects (mostly flies) are attracted to the ooze and help spread the pathogen in their visits to other trees (Miller & Schroth 1972). Such early dispersal up to several weeks *before* infection accounts for the often "explosive" nature of fire blight epidemics (Miller & Schroth 1972). The bacteria have the ability to survive and multiply on various plant surfaces and are dispersed again and again under favorable conditions. Thus, the risk posed by a single canker source in an orchard is magnified many times.

The bacteria reach the first open flowers by wind, rain splash and by casual insect activity. Once colonization of the stigmas begins, however, further dispersal of the pathogen during bloom occurs mainly by pollinating insects. The bacteria are capable of multiplication and survival for some time on the surfaces of leaves and blossoms (Miller and Schroth 1972, Thomson 1986). Most important from the standpoint of blossom blight is the fact that exposed apple flower stigmas are readily and selectively colonized by the bacteria to very high levels (Thomson 1986). *Underestimating this risk for early colonization by bacteria supplied from just a few cankers in and around the orchard has caught many growers*

unprepared in protecting open blossoms from infection.

Blossom blight. The occurrence of blossom blight is one of the most sporadic aspects of fire blight epidemics. The **Maryblyt™** model was built on the assumption that there is an abundance of inoculum and that, for a blossom infection event to occur, four strict conditions must be met in sequence. These conditions and the required sequence are:

- Flowers must be open with stigmas exposed for colonization and petals intact [flowers in petal fall are resistant];
- Accumulation of at least 198 DH > 65 °F (110 DH > 18.3 °C) within the last 80 DD > 40 °F (44.4 DD > 4.4 °C) for apples or within the last 120 DD > 40 °F for pears [defines the epiphytic infection potential for the oldest open and, hence, most colonized flower in the orchard];
- A wetting event occurring as dew or ≥ 0.01 inch (0.25 mm) of rain, or ≥ 0.10 inch (2.5 mm) of rain the previous day [allows movement of bacteria from colonized stigmas to the nectarthodes]; and,
- An average daily temperature of ≥ 60 °F (15.6 °C) [this may influence the rate at which the bacteria migrate into the nectarthodes as well as the multiplication of bacteria needed to establish infections].

When all four of these *minimum* requirements are met in the sequence shown, infections occur and the first early symptoms of blossom blight can be expected to appear with the accumulation of an additional 103 DD > 55 °F (57 DD > 12.7 °C). *In real time, this interval can vary from 5 to 30 (or more) days depending upon the prevailing temperatures.* The occurrence of blossom blight symptoms a month after bloom is not at all unusual and seems especially true in moderate to cool climates. Since infections initiated in response to a single rain or dew event can occur within minutes, it is also characteristic for most symptoms to develop simultaneously. This may be one reason why symptoms appear suddenly rather than gradually and show about the same degree of wilt or necrosis when they first appear. As the epidemic progresses, however, the severity of individual infections varies due to multiple infection cycles and the physiological status of the tissues involved.

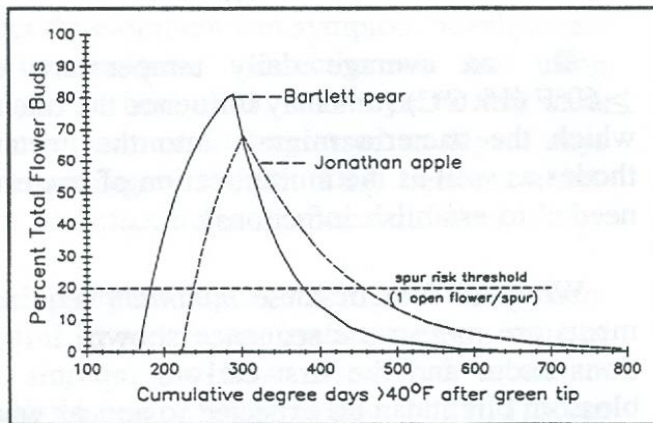


Figure 1. Proportion of total flower buds with open blooms on Bartlett pear and Jonathan apple as a function of cumulative degree days > 40°F (4.4°C) after green tip.

When the orchard conditions are less than these minimum requirements, few or no symptoms occur and no significant epidemic develops. However, *the degree to which any one or more of these thresholds is exceeded provides a subjective basis for estimating the severity of any given blossom infection event.* Thus: many open flowers pose a greater risk than few or no open flowers (i.e., more infection sites); an EIP of 200-300 poses a greater risk (i.e., more flowers colonized) than a marginal EIP of 100; thorough wetting by heavy dew or prolonged rain is more important than intermittent showers; and, average temperatures > 60 °F are likely to support more infections.

Figure 1 illustrates the predictable blossoming patterns typical for apples and pears in response to DD > 40 °F (4.4 °C). While the greatest proportion of open (=susceptible) flowers occurs at full bloom, the risk period for damage to fruiting spurs is much longer. This is because single flower infections usually destroy the supporting spur. Thus, the period between 20% bloom and 80% petal fall, when there is at least one colonized but uninfected blossom per spur, represents an extended period of high risk.

Not all flowers in the orchard open (=susceptible) or begin petal fall (=resistant) at the same time. Because all of the flowers open on any one day have not been equally exposed for colonization by the bacteria they are not all equally subject to infection. Only those flowers that have been open long enough for colonization are likely to become infected. This helps explain the often erratic differences in the number of infections that occur with different cultivars in the same orchard. Figure 2 was adapted from research on pears in California (12) and shows the rate at which open flowers are colonized by the pathogen as a function of cumulative DH > 65 °F (18.3 °C). A similar relationship seems true for apples (7).

While the estimates for spur loss shown in Figure 3 are useful for estimating maximum risk, they should not be used when deciding whether a particular infection event is severe enough to justify treatment. On the contrary, *treatment decisions for blossom blight should be based strictly on whether an infection event is expected or has occurred, not on how severe it might be.* This is because even a few early blossom infections provide many new sources of bacteria throughout the orchard to fuel a later epidemic of shoot blight.

Cool weather has a negative effect on the epiphytic infection potential, EIP. The rate

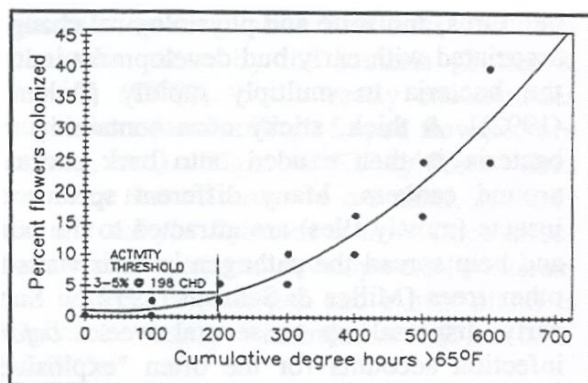


Figure 2. Proportion of open flowers colonized by *E. amylovora* as a function of cumulative degree hours > 65 °F (18.3 °C). Data were developed by Zoller and Sisevich (1979) for pears in California and shows a threshold of 198 Fahrenheit or 110 Centigrade degree hours that appears to be necessary to support an epidemic of blossom blight. With the modifications on the accumulation of degree hours used in the *Maryblyt*™ program, this threshold has worked well for both apples and pears.

warm weather to several times over the minimum threshold poses a very high risk because more open flowers are colonized.

A wetting event during bloom provides a means for the bacteria colonizing the stigmas to move down into the nectarthodes at the base of the flower where infections take place (Thomson 1986). The presence of a continuous film of water between the stigma and the nectary may allow substances in the nectar to establish a chemical gradient, which the bacteria can detect and follow into the infection sites (Bayot & Reis 1986). From a risk standpoint, a heavy dew may contribute to more infections than a small rain shower because of the thoroughness of wetting that occurs in a greater number of flowers. This may explain why blossom blight occurs more frequently and more severely in low areas of the orchard where heavy dew is common.

at which flower buds open slows and the rate that bacteria colonize flowers is reduced. Also, at temperatures above 40 °F (4.4 °C) some already colonized, but uninfected, flowers will continue to mature and become resistant as they enter petal fall.

A 3-day cool period during bloom can reduce the risks for blossom blight significantly. For this reason, the *Maryblyt*™ program reduces the risk for infection due to cool weather by making incremental reductions in the cumulative DH total. For one and two consecutive days with no temperature above 64 °F (17.8 °C), the total DH accumulation is reduced first by one-third and then by one-half, respectively, and to zero for a third consecutive cool day or in response to any one day with a freezing temperature. Once the DH total exceeds 400 (EIP = 200), however, no negative adjustments are made. Conversely, an increase in the EIP during

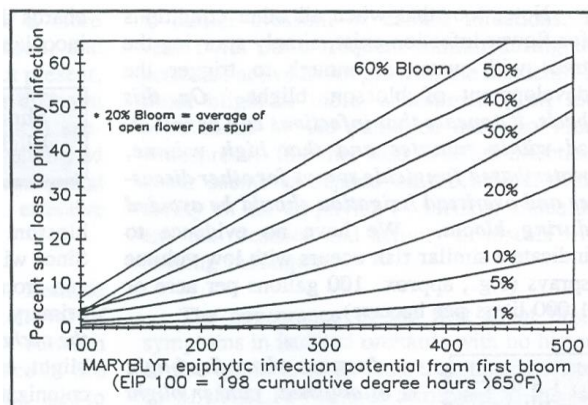


Figure 3. Estimates of Jonathan apple spur loss due to fire blight at various stages of flowering. Values shown are only approximate based on the percent of total flower buds (shown in Fig. 1) multiplied by the percent of open flowers colonized (shown in Fig. 2) assuming blooms are uniformly distributed over the population of fruiting apple spurs, each consisting of five flower buds.

Note, too, that when all other conditions for flower infection exist, simply spraying the trees with water is enough to trigger the development of blossom blight. On this basis, it appears that infections can be initiated within minutes and that high volume, water-based fungicide sprays for other diseases and overhead irrigation should be avoided during bloom. We have no evidence to indicate a similar risk occurs with low volume sprays (e.g., approx. 100 gallons per acre or 1,000 liters per hectare).

Canker blight. *In areas where fire blight is established, canker blight should be expected every year* (Steiner 1990b). These symptoms are often overlooked or mistaken for early shoot blight and may be triggered by the active vegetative growth phase of the host tree (Suleman 1992). This event can be predicted quite reliably with the accumulation of at least 196 DD > 55 °F (109 DD > 12.7 °C) after green tip (usually about petal fall \pm one week) (Steiner 1990b). Typical canker blight symptoms (CBS) that result from the internal invasion of nearby vegetative shoots by the bacteria follow canker margin symptoms (CMS) with the accumulation of an additional 103 DD > 55 °F (57 DD > 12.7 °C).

When blossom blight is severe, canker blight symptoms can be easily overlooked. Also, when compared to the large amount of inoculum available from infected blossom clusters, such late canker activity probably adds little to the overall risks for shoot blight. However, when blossom blight does not occur or is very light, these active cankers represent a primary source of inoculum for the shoot blight phase. Thus, orchards must be monitored closely when canker blight symptoms are expected (about 300 DD > 55 °F or 167 DD > 12.7 °C after green tip). Prompt removal of these active cankers *before* extensive necrosis develops should help delay the appearance of shoot blight. This seems especially true in orchards that are isolated from other sources of inoculum.

Shoot blight. For shoot blight to occur, there must first be a local source of inoculum. This is available from tissues showing symptoms of either blossom or canker blight (Steiner 1990b). Since wind and insects can disperse the pathogen from other orchards and wild trees, the primary inoculum sources *need not be within the orchard being monitored*. As with blossom blight, early dispersal of the pathogen and its colonization of foliar surfaces well before infection occurs seems to be common with the shoot blight phase of fire blight epidemics.

The exact mechanism and the amount of inoculum needed for shoot tip infections is not known, but, insects with sucking or piercing mouthparts seem to be clearly involved in many locations. Our observations suggest that bacterial colonies may develop independently on leaf surfaces, having arrived there via rain, wind or by casual insect visits. Actual inoculation then occurs later when various insects with sucking mouthparts arrive and begin probing any of the top three shoot tip leaves in search of a suitable feeding site. In a fewer number of cases, the bacteria may be transmitted to a healthy shoot tip by an insect that has fed previously on other tissues containing the pathogen, but not yet showing symptoms.

Which insects are most important in contributing to shoot blight epidemics will, undoubtedly, vary from site to site and from region to region. In Maryland, and many other

parts of the U.S., early shoot blight symptoms are most closely associated with the activity of winged adults of the white apple leafhopper. These are first available about 675 DD > 40 °F (375 DD > 4.4 °C) after green tip. In areas where the white apple leafhopper is not known, the accuracy of shoot blight predictions should be improved by changing the vector availability threshold for a more appropriate vector. Later in the season, and where white apple leafhoppers are not present, suitable insect vectors may include different species of leafhoppers and other insect species. Clarke, et al. (1992) published information from Pennsylvania indicating that the green apple aphid is *not* an effective vector for the fire blight bacterium.

Identifying insect vectors. Because of the standard and very reliable interval of 103 DD > 55 °F (57 DD > 12.7 °C) between infection and the first early appearance of fire blight symptoms, **Maryblyt™** can be used to help identify different insect vectors contributing to shoot blight. By observing precisely when the first shoot blight symptoms appear and then subtracting 103 DD from the total DD > 55 °F shown on the program printout for that day, the day on which the infection occurred can be identified. Records of insects with piercing or sucking mouthparts trapped in the orchard on or about the identified "infection-day" can then be used to identify potential vectors. Further studies to identify a DD > 40 °F threshold from green tip when that insect is first available after blossom or canker blight symptoms appear can then be used for prediction by entering that threshold in the **Maryblyt™** program.

Shoot blight forecasts using **Maryblyt™** are limited to only the *first* early shoot blight symptoms and are based on the assumption that insect vectors are present. These early symptoms usually develop with the accumulation of 103 DD > 55 °F (57 DD > 12.7 °C) after the first appearance of either blossom or canker blight symptoms in the immediate area when: (a) the average daily temperature is 60 °F (15.6 °C) or above, *and* (b) suitable insect vector populations are present. After the first appearance of shoot blight, new infections are incited within the infected tree, to adjacent trees, and ultimately at random within a block of trees (depending on populations of bacteria, tenderness of tissue on shoot tips, insect activity on shoot tips, and frequency and intensity of wind-driven rain) until vegetative growth is complete (Biggs et al. 2008). Rain and wind help distribute the bacteria but they do not appear to be required for shoot blight to occur. Thus, in dry seasons, new shoot infections often appear limited to sites fairly close to earlier blossom or canker infections. In years with more frequent rainfall during the period of active shoot growth, the incidence of shoot blight is more widespread (i.e., leaf populations of the pathogen are also more widespread). In either case, whether infections occur seems to depend on the overall availability of an epiphytic (=surface) inoculum and the presence and activity of insects with sucking mouthparts.

The appearance of the first shoot blight symptoms in isolated orchards with no history of fire blight is often later than that predicted by **Maryblyt™** and is attributed to the late arrival of the pathogen from some distant source or late developing populations of insects with sucking mouthparts. This latter factor can also be influenced by insecticide treatments by the grower. In either case the number of shoot blight infections should be small; if they are numerous and widely dispersed, however, then look for another vector.

Trauma blight. Trauma blight is an unusual form of fire blight in which infections are associated with injuries caused by late frosts ($\leq 28^{\circ}\text{F}$, -2.2°C), hail or high winds that damage foliage or flowers (Steiner 1990b). The actual risks for loss vary with the severity of the injurious event and the epiphytic population of the bacteria present when it occurs. Trauma blight incidents can be expected any time after early bloom when the EIP reaches 100, but are generally more severe when the EIP exceeds 200-250. While free water on the surfaces of leaves is likely during a late frost event or with hail, infections do occur in the absence of rain under high wind conditions that tatter the foliage or damage blossom clusters. However, if rain accompanies the high wind or follows it closely, the damage is likely to be much greater.

The precise mechanisms by which the pathogen becomes established following foliar injury is not known. Research at the University of Maryland indicates that the normal maintenance functions of mature tissues may confer resistance to symptom development despite the presence of the bacteria within the tissues of normally susceptible cultivars [Suleman 1992]. The extensive damage to tissues caused by frost, hail and high winds is thought to breach this natural defense mechanism, allowing the pathogen ready access to the materials it needs. A similar effect is seen when an attempt is made to cut out active infections during the season. Once injury occurs, symptoms can be expected following an interval of $103\text{ DD} > 55^{\circ}\text{F}$ ($57\text{ DD} > 12.7^{\circ}\text{C}$) [similar to the infection-to-symptom interval shown for all other phases of fire blight].

SUMMARY

Fire blight is a complex disease that can develop in a variety of distinct phases during the course of a season, not all of which occur every year or with the same intensity. Blossom blight is usually the first phase to develop and is most destructive in bearing orchards. Canker blight symptoms generally begin during late bloom, but may not be clearly visible on young shoots near canker sites until 1-2 weeks after petal fall. Tissues showing either blossom or canker blight symptoms provide a source of inoculum for the subsequent development of shoot blight. Shoot blight is often most destructive in non-bearing orchards where rapid vegetative growth is encouraged, but it also can result in much damage to major scaffold limbs in bearing orchards. Trauma blight is an unusual phase of fire blight where infections occur through injuries caused by severe weather events and can affect mature tissues that might otherwise exhibit resistance. Each phase develops in response to different conditions and can appear alone or in combination in any given orchard or season. Any incidence of blossom, shoot or trauma blight symptoms can lead to the loss of entire trees due to the subsequent development of rootstock cankers where susceptible rootstocks are used. Because the pathogen multiplies rapidly and is dispersed widely well before infection events occur, major epidemics can develop quickly even where the incidence of the disease has been low. Thus, once fire blight is known to occur in an area, good control is possible only through rigorous monitoring and an aggressive management program.

Part II. MANAGING FIRE BLIGHT:

A Guide for Disease Management Decisions Using *Maryblyt*[™]

INTRODUCTION

Consistent fire blight control requires an aggressive management approach that includes both long and short term measures in a *planned strategy*. The *Maryblyt*[™] program is designed to aid in the decision making needed to support such a strategy by:

- (1) Signaling periods of high risk;
- (2) Identifying specific infection events;
- (3) Predicting symptom appearance; and,
- (4) Prompting appropriate treatments when they might be most effective.

Part I of this manual explained the biological bases for the various phases of fire blight epidemics. Here, our focus is on developing an effective disease management strategy. The specific tactics used include pruning, fertility management, cutting out active infections and spraying with copper materials, antibiotics and insecticides at appropriate times. Not all of these tactics are useful against all phases of fire blight and the *timing* for these treatments is often very critical.

DEVELOPING A FIRE BLIGHT MANAGEMENT STRATEGY

Dealing with fire blight is not unlike dealing with any other disease or insect pest, with several important exceptions.

- (1) The bacterial pathogen has the capacity at certain temperatures to double in number every 20 minutes at 70 °C (1 to over 1 trillion+ cells in just 10 hours), giving rise to enormous amounts of inoculum in a very short time.
- (2) Outbreaks occur erratically because of multiple and specific requirements for infection that occur differently among orchards and cultivars even when those varieties are similar in their genetic susceptibility.
- (3) Fire blight epidemics tend to be explosive because literally thousands of infections can occur within minutes throughout an orchard or area.
- (4) Symptoms that result from a single infection event develop simultaneously and appear suddenly 5-30 days later when little can be done to stop the infection process.
- (5) Fire blight epidemics develop in a series of distinct phases, each of which have different requirements for infection and requires different tactics for control.

Our goal is not to eradicate the pathogen (an impossible task), but to limit its distribution and the amount of damage it causes. This is done by focusing on efforts to reduce the *number* and *distribution* of inoculum sources available for initiating infections *at each phase* of the epidemic, and to reduce the rates at which infections occur. The first approach has the effect of delaying the epidemic while the latter slows the progress of the epidemic. In either case, the right tactics must be used at the right time relative to the risks present.

Only by specifically addressing each phase of a potential fire blight epidemic is it possible to maintain what can be considered consistent control year after year. Thus, excellent control of blossom blight in one season may have little impact on the blight risks in the *next* season if measures have not also been taken to limit the incidence of canker and shoot blight that occur the same year. Similarly, if blossom blight is well controlled but the symptoms of canker blight in the *same* season are ignored, then a serious outbreak of shoot blight may well follow. This latter situation often leads to the false conclusion that blossom sprays with streptomycin or another material were *not* effective since fire blight developed anyway. Since each of these phases develops in response to different conditions, the tactics required for control also are different.

The following management program is presented chronologically based on the phenological development of apples and pears and assumes that the fire blight pathogen, *Erwinia amylovora*, is well established in or near the orchard. Nevertheless, even where the incidence of fire blight is rare and overall inoculum levels are low, epidemics can develop so rapidly that close attention to the management details presented here is still necessary to prevent serious losses.

Our experience suggests that aggressive management of fire blight in years when the incidence of disease is low can have a major impact on the severity of blight in subsequent seasons. In areas where other susceptible alternative host species [hawthorn (*Crataegus* spp.), fire thorn (*Pyracantha* spp.), quince (*Cydonia* spp.), ash (*Sorbus* spp.) and *Cotoneaster* spp.] are common, the potential for these hosts as sources of inoculum must also be considered.

Recommendations on the use of streptomycin, oxytetracycline and kasugamycin antibiotics are based on their registration in the United States. These materials may not be available or permitted for use elsewhere. Likewise, the use of materials not registered for use in the United States is not considered.

DORMANT PERIOD

PRUNING

Dormant pruning of all blighted limbs, shoots and cankers must be done every year to reduce the number and distribution of inoculum sources in and around the orchard before the bacteria can be dispersed in the early spring. This sometimes requires difficult decisions in removing large limbs or whole trees for which there is still some bearing potential. That benefit, however, must be weighed against the added risks and costs of keeping an inoculum source available in the orchard. Consider, too, the cost of retraining a severely damaged tree to fill its allotted space and return it to full productivity versus replacing the tree and protecting it well. Again, when the incidence of fire blight is low, the complete removal of a few trees has relatively little overall economic impact but can have a major influence on future disease outbreaks.

Removing wild or neglected fruit trees and other fire blight susceptible host plants from fencerows and areas near producing orchards should also be done whenever possible.

Removing all blighted wood from the trees has other benefits in that this dead wood frequently harbors several fungal pathogens, which contribute to summer fruit rot problems (e.g., black rot, white rot, bitter rot). While whole trees and large limbs should be removed from the orchard after dormant pruning, smaller branches can be raked to the row centers and mulched with a flail mower to destroy their effectiveness as sources of inoculum for all of these diseases.

PRE-BLOOM PERIOD

FERTILITY

Orchards receiving excessive amounts of nitrogen appear to be more susceptible to fire blight. One reason for this is that vegetative shoots remain succulent and attractive to insect vectors longer. Because the extent to which infections progress within growing limbs decreases with maturity, it is important to limit the period of active vegetative growth. For this reason, new orchards should be established using only moderate amounts of nitrogen fertilizers that will promote growth that is adequate without being excessive. Thereafter, nitrogen amendments to the soil should be based on a visual assessment of foliage color, on overall extension growth and the results of foliar analyses. Legume cover crops that fix large amounts of nitrogen (alfalfa, clover, vetch, etc.) should be avoided.

TREE STRESS

While trees showing excessive vegetative growth tend to be more subject to shoot tip infections, trees under stress (e.g., poor nutrition, poorly drained sites, and sites with high soil populations of plant parasitic nematodes) often appear to suffer more limb and trunk damage. This does not mean that stressed trees are subject to *more* infections than non-stressed trees, but only that the damage following infection is often more severe. Trees on poorly drained sites also may tend to continue active shoot growth for longer periods. Recent research suggests that trees under stress may be less capable of resisting the progress of infections because of lower carbohydrate reserves.

EARLY COPPER SPRAYS

Copper-based products applied at, or just before, green tip do not kill the bacteria inside cankers. Their purpose is to reduce the efficiency of overwintering inoculum in colonizing bark and bud surfaces during the pre-bloom period. Documented results with such treatments have been largely inconsistent. Nevertheless, the treatment is fairly inexpensive and can be made in combination with conventional horticultural oil treatment for mites, scale and aphid insect control. This treatment is most important in years following a moderate to severe incidence of fire blight where the number of overwintering cankers is likely to be high. The inconsistency in control with early copper sprays may well be due to the timing of the treatment relative to when the inoculum is first available. For example, most treatments are made when the trees are still dormant or just at bud break, which can be several weeks before bacterial ooze is first available and the colonization of tree surfaces begins. A second copper spray later in the season just before bloom may afford better protection against blossom blight. However, *most available copper formulations can cause moderate to severe foliar and fruit injury if applied later than the green tip stage on most apple*

and some pear cultivars.

No copper spray treatment is completely effective because of coverage faults, the availability of inoculum from outside the orchard and the later colonization of unprotected new growth. In addition, since the dispersal of bacteria is more or less random, even resistant trees like Red Delicious interplanted with susceptible varieties (both production varieties and those used as pollinizers) can be colonized by the pathogen and serve as reservoirs of inoculum for later dispersal during bloom. Thus, *where copper materials are applied, the entire orchard block, including non-susceptible cultivars should be treated rather than only those trees of susceptible varieties.*

BLOOM PERIOD

Making fire blight control decisions during the bloom period is difficult because few symptoms appear during bloom and most decisions on preventive spray treatments must be made on anticipated risk. Blossom blight is usually (but not always) the earliest phase of a fire blight epidemic. It can be extensive because of the large number of susceptible infection sites, because flowers are readily and selectively colonized well in advance of infection and because inoculation occurs within minutes when the blossoms become wet (rain, dew, spray). Blossom blight is most destructive in bearing orchards because of damage to the crop, loss of fruit bearing surface, and because these early infections can provide thousands of new sources of inoculum for a continuing epidemic of shoot blight. Even where the number of infected blossoms is relatively low, the risk of shoot blight problems is high. The extent to which limbs are invaded following flower infections that occur during late primary bloom or on late developing secondary flowers is often greater than that seen following earlier blossom infections. This may be related to the effects of rapid vegetative growth which, in turn, reduces the acquired physiological resistance of older growth to damage by the pathogen.

ANTIBIOTIC SPRAYS

Blossom sprays with antibiotics like streptomycin or kasugamycin on apples and either streptomycin or oxytetracycline on pears have been recommended in the past at 3- to 5-day intervals during the bloom period to prevent blossom blight. Without a reliable system for predicting specific infection events, this frequency was necessary to ensure that all blossoms were protected all the time. This approach is generally adequate, but it sometimes fails (timing faults) and often proves to be excessive (i.e. when *all* conditions for infection are not present). Some of the inconsistent performance of blossom sprays is related to the antibiotics themselves (mode of action and resistance) and to poor coverage in making the applications, but the principal fault seems to lie in the precise timing of the sprays.

Antibiotic mode of action. Streptomycin has limited systemic activity in plants and tends to inhibit the multiplication of bacteria rather than killing them directly. For these reasons, it is best used for protection rather than to eradicate large existing populations of bacteria or to stop infections already underway. *Antibiotics for blossom blight are most effective when they are applied the day before or the day of an infection event.* Sprays applied

too late after an infection event, cannot stop infections in progress. A delay of even 24 hours after infection, especially under warm conditions, still allows the establishment of many infections. Nevertheless, if an application must be delayed for any reason, limited tests show the level of control obtained up to 48 hours after infection is still usually better than no treatment (W.H. Shaffer, University of Missouri, unpublished data).

Streptomycin resistance has been reported from many locations throughout the U.S. In nearly every instance, however, this has occurred where the antibiotic was used routinely more than six times per year. By comparison, where streptomycin use has been limited to less than 3 or 4 sprays per year for blossom blight, the material continues to be effective even after 30 years of use. The potential for resistance to oxytetracycline is expected to be similar. In our experience with the *Maryblyt*[™] program, one or two *well-timed* streptomycin sprays are sufficient to prevent blossom blight in most orchards in most years.

Phenological factors. Blossom sprays protect only those flowers that are open at the time of treatment. Thus, the protective value of an application made too early can be lost quickly with the opening of many new flower buds. The rate of flowers opening on Jonathan apples, for example, is approximately 1 percent per 1.5 DD > 40 °F (0.83 DD > 4.4 °C) so that in just one or two warm days nearly 20% more buds may open. This poses a risk of approximately one unprotected flower per spur. *Such risk is often underestimated.*

Table 1. *Maryblyt*[™] system for reporting the minimum risk for a blossom infection event.

Risk of infection	Requirements for infection			
	Bloom	DH>65°F	Wetting	Ave>60°F
NONE	-	NA	NA	NA
LOW	+	-	-	-
MODERATE	+	+	-	-
or	+	-	+	-
or	+	-	-	+
HIGH	+	+	+	-
or	+	+	-	+
or	+	-	+	+
INFECTION ²	+	+	+	+

¹ Accumulation of a minimum of 198 DH > 65 °F (110 DD > 18.3 °C) over the last 80 or 120 DD > 40 °F (44.4 or 66.7 DD > 4.4 °C) after the start of flowering for apples or pears, respectively.

² First symptoms can be expected with the additional accumulation of 103 DD > 55 °F (57 DD > 12.7 °C) from the date of infection.

Spray application factors.

The specific spray targets for blossom sprays of streptomycin (and other materials) are the flower stigmas (selectively colonized by the bacteria) and the nectary in the flower base (where most infections occur). Thus, orchard sprayers must be properly calibrated, adjusted, and used in a manner that ensures the antibiotic is delivered into all open blossoms. Adding a good *surfactant* or *activator adjuvant* to the spray mix improves the delivery and coverage of the antibiotic to the stigmas and nectaries. Poor control can occur where antibiotics are applied on an alternate row middle basis as is often done in treatments for

other diseases during bloom (e.g., apple scab). Note, too, that applying fungicides or plant growth regulators during bloom using high volumes of water can provide the wetting event

necessary for infection when all other conditions for blossom blight are present. In one Missouri trial (W.H. Shaffer, unpublished), simply spraying trees to the drip point with water during the bloom period resulted in 227 strikes per tree.

RISK FACTORS

Table 1 illustrates the way in which the *Maryblyt*[™] program identifies the risks for a blossom infection event. This is *not* a severity rating, but only an indication of the risk that an infection event is likely. The basis for deciding whether to apply a bloom spray or to delay that treatment lies in using *Maryblyt*[™] in its real time mode to establish current risks in the orchard and then using the program's prediction option to simulate the risks expected using weather forecasts.

A blossom spray is recommended when the risk is high and when an infection event is predicted for the next day. Under high disease pressure, or where a lengthy storm is forecast, or where a large area of orchard must be covered in a short time, it may be advisable to begin treatments when the risk is only moderate (i.e., two of the four critical conditions exist). As noted in Part I, because of the high risk for secondary infections following early blossom infection, *treatment decisions for blossom blight should be based strictly on whether an infection event is expected or has occurred, and never on how severe that event might be.* *Maryblyt*[™] indicates when conditions suggest a spraying decision is needed.

POST BLOOM TO TERMINAL BUD SET

The 6 to 8 week period after petal fall is a very important time for fire blight management decisions. During this time: (1) blossom blight symptoms appear if infections occurred during bloom; (2) canker blight symptoms appear within the first 3 weeks after bloom in orchards with a history of fire blight; (3) the risk for shoot blight increases and continues until shoot growth ceases; and, (4) severe storms (wind, hail) are more likely to contribute to trauma blight.

Control measures taken here will do much to limit the amount of disease in the current year and the amount of inoculum available for the next season. As bacterial populations in the orchard increase, the potential for shoot blight increases with the activity of sucking insects. This is also true for trauma blight incidents should severe weather occur. With the exception of late secondary flowering, *the focus of the control effort must now shift from preventing blossom blight to limiting the damage caused by canker blight and to reducing the potential for serious damage with shoot and trauma blight events.*

ANTIBIOTIC SPRAYS

Antibiotic sprays after primary petal fall are specifically not recommended except where a significant amount of secondary flowering extends the period of risk for blossom infections. In any case, the number of antibiotic applications per season should not exceed four to reduce the potential for selecting resistant populations of the pathogen. This presents a problem where secondary flowering prolongs the period of susceptibility to blossom blight. Streptomycin is ineffective as a protectant for shoot blight. In addition, because of the

high potential for selecting resistant strains of the pathogen, streptomycin should *never* be used after symptoms of blossom blight appear in the orchard.

Whether streptomycin should be used *after* severe weather damage (hail, high wind, and late frost) to protect against trauma blight is still a matter for debate. There are no data on its effectiveness or economic value under these conditions. Nevertheless, if this approach is taken, consider the following factors in making a treatment decision: (a) susceptible cultivars are damaged; (b) the orchard has a history of fire blight; (c) the application can be made within the allowed pre-harvest interval for the crop; (d) the application can be made within 24 hours; and, (e) the value of the planting justifies the cost of the application.

The plant growth regulator, Apogee (prohexadione-calcium), is registered for suppression of fire blight shoot blight. Shoot blight suppression results from hardening off of vegetative shoot growth starting about 10 days after the initial Apogee application, which should be made at late bloom when active shoot growth is 1-3 inches long. Recent studies at Winchester, VA, indicate that Apogee may be tank-mixed with streptomycin and an adjuvant (such as Regulaid), allowing Apogee to take effect while there is residual protection from streptomycin. Apogee is not to be considered a replacement for streptomycin sprays for blossom blight control. Registered rates for Apogee are 6-12 oz./100 gal dilute or 24-48 oz./acre. To reduce interference from naturally occurring calcium in the water used for spraying, ammonium sulfate should be added to the tank before Apogee, at the same rate per 100 gal. of spray mix as for Apogee. Based on research at Winchester, VA, the combination of 6 oz. of Apogee plus 6 oz. of ammonium sulfate per 100 gal. is suggested for moderately vigorous trees. An adjuvant such as Regulaid should be included to increase systemic uptake of Apogee. Vigorous trees might be more responsive to the 12 oz. than 6 oz. Apogee rate.

Shoot blight suppression is related to early hardening off of shoot tip growth within 10-14 days after bloom. Vigorous trees might benefit from further protection with additional Apogee applications in mid-season if shoot growth is resumed. Studies in Kearneysville, WV, showed that Apogee reduced shoot blight infections that occurred with hail injury in June. Do not apply more than 48 oz./A within a 21-day period. Practical usefulness of Apogee for shoot blight suppression in a given year might be estimated by the potential severity of fire blight based on the number of infection days that occurred during the bloom period, as well as tree vigor, varietal susceptibility, and disease history. Apogee treatment for shoot blight suppression would be most strongly suggested for vigorous young trees that have nearly filled their tree space. Apogee must be further tested to determine whether its application will reduce the progression of fire blight bacteria into the rootstock.

INSECTICIDE SPRAYS

Insecticide treatments for insect vectors associated with fire blight (leafhoppers, plant bugs, and psylla) should be maintained during the rapid vegetative growth phase of the trees to reduce the incidence of shoot blight. Treatment should begin when blossom or canker blight symptoms appear and, preferably, just as the suspect insect species begin to appear (i.e., *not* later when economic damage levels associated with these insect populations is reached). Where treatments are delayed until shoot blight symptoms appear, newly

blighted shoots are likely to continue appearing for a week or more because of infections established earlier.

Where the availability of a specific known insect vector can be predicted on the basis of cumulative DD > 40 °F (4.4 °C) from green tip, the **Maryblyt™** program can be used to provide a warning and to suggest a time to start insecticide treatments. The **Maryblyt™** program automatically defaults to 675 DD > 40 °F (375 DD > 4.4 °C) to signal the availability of first generation winged white apple leafhopper adults (nymphs are present earlier but lack wings). This threshold level can be changed by selecting 'Set Thresholds' under the Options menu. See Part I, page 12, on using **Maryblyt™** to identify other insect vectors.

CUTTING OUT INFECTIONS

Cutting out infected shoots and limbs during the current season has been debated for some time because of inconsistent results. Much of this inconsistency may have been due to the lack of an overall disease management strategy and because the cutting procedure was often delayed for various reasons. In our experience, the practice can be beneficial during some epidemics but *only* if careful attention is given to why, when and how it is done.

Why cut out active infections? By detecting symptoms *early* and promptly removing them, *before* extensive necrosis develops, the number and distribution of inoculum sources and, hence, the potential for secondary shoot infections can be reduced. This approach is not always possible since symptoms may not be detected early enough or they may be so numerous that the removal of all infected tissues within a reasonable time is both physically and economically impractical. The **Maryblyt™** program can help signal when monitoring for specific types of early symptoms should begin. See Table 2 on page 25 for details on early symptoms. The fire blight pathogen has the potential to move from orchard to orchard via insects and wind so monitoring efforts should not be limited only to those areas where fire blight was a problem in the previous season but in surrounding orchard blocks as well.

When to cut? *Pruning is most likely to be effective in those orchards and seasons where the incidence of fire blight is low or where small outbreaks are localized within the orchard.* Because of the exponential increase in the amount of disease that occurs with fire blight, the removal of inoculum sources must be *very thorough* to be effective. When the incidence of blight is already low, an active cutting program has the potential for reducing the number of sources to very low levels in a short time. When blossom blight does not occur or where its incidence is very low, close attention should be paid to the occurrence of early canker blight symptoms. These must be removed promptly and completely, even where the number of such sites may be limited to just a few per orchard to reduce the risks for shoot blight and to limit the number of cankers available next season.

Where the incidence of blight is high and extensive cutting is required, effective reduction in the inoculum potential for the current season is not likely to be accomplished within a reasonable time. Thus, *during severe epidemics, the primary focus of the cutting effort should be to salvage as much of the tree structure and bearing surface possible.* Give priority to young trees, to high density plantings where the trees are deliberately trained with little scaffold

limb structure and to infections that might invade the central tree stem or major bearing limbs. Small trees with little vegetative structure appear to be less capable of resisting the progress of infections so more limb damage often occurs. Finally, severely infected trees should be removed completely and as early as possible. *Avoid excessive cutting throughout the orchard, which can stimulate a flush of secondary vegetative growth and extend the period of susceptibility to shoot blight.* In these latter instances, major pruning is best delayed until dormancy.

How to cut? After infection, the pathogen often invades mature, healthy tissue up to a meter or more in advance of any visible symptoms. Such tissues, even on highly susceptible cultivars, have the ability to resist the damage that results in symptoms. However, the cutting process can breach this natural resistance mechanism so that small cankers are induced to form around the wound. *That these cankers form even where both the cutting tool and the bark surface are disinfested with alcohol suggests that the traditional practice of tool sterilization between cuts has little real value so long as only blighted tissue is being removed.* This is not true if cuts are made at the same time to remove healthy tissue as part of a tree training program. Here, all tools must be cleaned between each cut to avoid transporting and inoculating the bacteria. Wiping the tool blades with a 10% household bleach or 50-70% ethyl alcohol solution is usually adequate for this purpose.

The small cankers that form around cuts made to remove active infections usually develop within a couple of weeks, but are quite small and often go unnoticed. This is especially true when the cuts are made back to the next healthy limb as are most routine pruning cuts. Tests conducted in Maryland and Washington suggest that cuts can be made to isolate these small cankers for later removal. *This is done by making all cuts at an internode (i.e., do not cut back to a spur or bud) and into wood that is at least two years old, deliberately leaving a naked, 4 inch (10 cm) branch stub above the supporting limb.* The ugly stubs that remain allow these canker sites to be located easily and removed completely during the usual dormant pruning operation, when temperatures are too cold for the bacteria to colonize the wound. Marking the "ugly stubs" with flags or bright colored paint when the cuts are first made can help in relocating them during the winter pruning operation.

Pruning waste removal. The bacteria in and on freshly cut shoots and limbs removed during the growing season can remain viable and be available for continued dispersal in the orchard for some time. For this reason, all infected shoots and limbs removed during the active growing season should be collected and removed immediately from the orchard for destruction. If the amount cut cannot be removed quickly, there may be too much blight present for cutting to be effective.

LATE SEASON PERIOD

Once vegetative shoot growth has slowed or stopped by mid-summer, the risk for serious outbreaks of fire blight is relatively low. However, populations of the bacteria can persist for some time on leaf surfaces so that severe wind or hailstorms can still incite some trauma blight events. *Where symptoms of late shoot blight appear in the orchard, they should*

be removed promptly even though the number of infections may be relatively small and only minor damage occurs. Again, the purpose here is to limit the distribution of inoculum over a larger area for subsequent infections. In addition, in some years there may be a late season flush of renewed vegetative growth that will be susceptible to shoot blight.

Our experience suggests that aggressive management of fire blight in years when the incidence of disease is low can have a major impact on the severity of blight in subsequent seasons. In areas where other susceptible alternative host species [hawthorn (*Crataegus* spp.), fire thorn (*Pyracantha* spp.), quince (*Cydonia* spp.), ash (*Sorbus* spp.) and *Cotoneaster* spp.] are common, the potential for these hosts as sources of inoculum must also be considered.

SUMMARY

A good fire blight management program should limit the amount of damage that occurs during the current season *and* reduce the risks for following seasons. This begins with a thorough dormant pruning to remove all blighted limbs and cankers. In the spring, where fire blight has been a problem, an early application of a copper material at the green tip stage is advisable. Orchard conditions must be monitored closely during bloom so that sprays can be made just before all blossom infection events. After petal fall, the control program must focus on the *prompt* removal of any blossom, canker or shoot blight symptoms where this is feasible, and to treatments for potential insect vectors where necessary.

Table 2. Appearance and timing of types of fire blight symptoms.

BLIGHT TYPE	EARLY SYMPTOMS		INTERMEDIATE SYMPTOMS	LATE SYMPTOMS
	What to look for	When to look		
Blossom blight	Dark spots to streaks and/or ooze droplets on flower bud petioles.	103 DD > 55°F (57 DD > 18.3°C) after a predicted BB infection event (can be 5 – 30 days).	Wilt and discoloration of flower cluster.	Flower cluster and cluster leaves discolored or necrotic; spur canker may extend into supporting branch.
Canker blight	Narrow (1–2 mm), water-soaked or diffuse brown zone in green bark around margin of overwintering canker. Must cut through outer bark at canker margin to be seen. Vegetative shoots near active canker sites show orange discoloration and wilt at tips; some basal leaves will show dark streaks and discoloration.	196 DD > 55°F (109 DD > 12.7°C) after green tip. Most often appears about 1 – 2 weeks after primary petal fall, but can appear during bloom in seasons that are earlier/warmer than usual.	Dieback of vegetative shoots near canker sites; droplets of ooze often seen on shoots with symptoms.	Infected shoots near overwintering canker sites are necrotic. Infections often extend into the supporting branch or may girdle that supporting limb.
Shoot blight	Brown streaks in inner bark extending several cm from canker margins.	103 DD > 55°F (109 DD > 12.7°C) after the appearance of either BB or CB symptoms; most terminal shoots at this time show 10 – 12 leaves.	Varying amounts of necrosis on shoots.	Symptoms may progress from infected shoots into supporting limb. Severity of symptoms is generally greater on trees with excessive succulent growth or with marginal carbohydrate reserves.
Trauma blight	Vegetative shoot tips wilt; unlike early canker blight, these shoot tips remain green (no orange discoloration). Droplets of ooze sometimes appear on shoot axis.	103 DD > 55°F (57 DD > 12.7°C) after late frost, wind, or hail event.	Many vegetative shoot tips showing yellow to orange discoloration along with wilt and leaf discoloration.	Blight symptoms usually evident throughout the tree canopy and may involve shoots, limbs, spurs, and fruit.
Rootstock blight	Ooze droplets evident on bark surface of rootstock just below graft union. Internal bark tissues of rootstock showing necrosis.	Usually evident 2 - 4 weeks after blight symptoms develop on scion shoots or spurs. Not all trees showing blight symptoms on scion tissues will show symptoms of rootstock blight.	Sudden decline and death of some infected trees by mid-summer after infection of scions. Rootstock canker completely girdles tree.	Limb or tree showing early red foliage in late summer to early fall (canker symptoms on rootstock). Early decline of trees in spring following blight outbreaks and upward development of typical bark cankers into the scion trunk from the rootstock.

Part III: PROGRAM OPERATING INSTRUCTIONS

Maryblyt™ Version 7.1 is available for free download from West Virginia University – Kearneysville Tree Fruit Research and Education Center. We express our thanks to the University of Maryland, the Estate of Paul W. Steiner, and Gary W. Lightner for allowing free distribution of the software for the benefit of the fruit growing community. We express our thanks to Eric Sonchaiwanich and Walter Britton for their programming expertise in the development of **Maryblyt™** Ver. 7.0 and 7.1, respectively.

SYSTEM REQUIREMENTS

Maryblyt™ 7.1 requires Microsoft Windows XP, Vista, Windows 7, or Windows 8 operating system or later. The compiled program requires about 5.5 Mb of disc space and individual files normally range from 3 to 6 kb.

INSTALLING OR UPDATING **Maryblyt™**

Run setup.exe and follow the setup wizard instructions. By default the **Maryblyt™** program files will be installed to \Program Files\USDA\Maryblyt. You do not need to uninstall any previous versions of **Maryblyt™** in order to install **Maryblyt™** Version 7.1. If you who received a trial version of **Maryblyt™** version 5.0 for Windows, you should delete that version from your computer either before or after installing Version 7.1.

RUNNING **Maryblyt™**

Maryblyt™ may be accessed from the Windows Start Menu. When **Maryblyt™** is run, the Main Window appears with cycling different background photos.

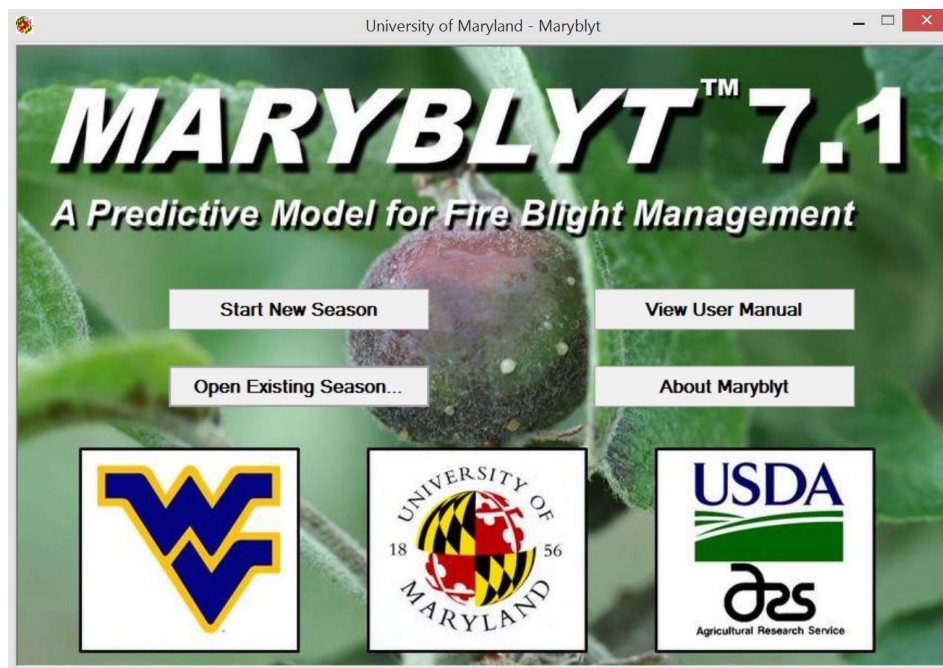
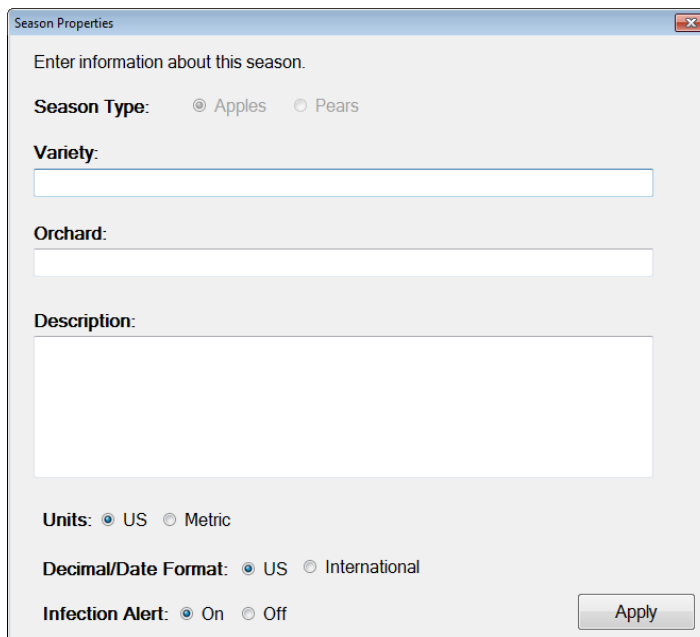


Figure 4. Main Start Window

CREATING A NEW SEASON FILE

To create a new season file, press the **Start New Season** button on the Main Start Window (Figure 4). The following dialog will appear (Figure 5):

Enter the season type (Apples or Pears) and enter information about the season. The variety, orchard, and description entries are optional. Select either U.S. or metric units of measurement, decimal/date format for US or International and whether you want an audible (beep) infection alert. Press OK when finished. This information will be saved with the season file. This information can be edited at a later date by accessing **Season Information...** under the Options menu.

A dialog box titled "Season Properties" with a close button in the top right corner. The text "Enter information about this season." is at the top. Below it are several fields: "Season Type:" with radio buttons for "Apples" (selected) and "Pears"; "Variety:" with a text input field; "Orchard:" with a text input field; "Description:" with a larger text area; "Units:" with radio buttons for "US" (selected) and "Metric"; "Decimal/Date Format:" with radio buttons for "US" (selected) and "International"; and "Infection Alert:" with radio buttons for "On" (selected) and "Off". An "Apply" button is in the bottom right corner.

Season Properties

Enter information about this season.

Season Type: ☒ Apples ☐ Pears

Variety:

Orchard:

Description:

Units: ☒ US ☐ Metric

Decimal/Date Format: ☒ US ☐ International

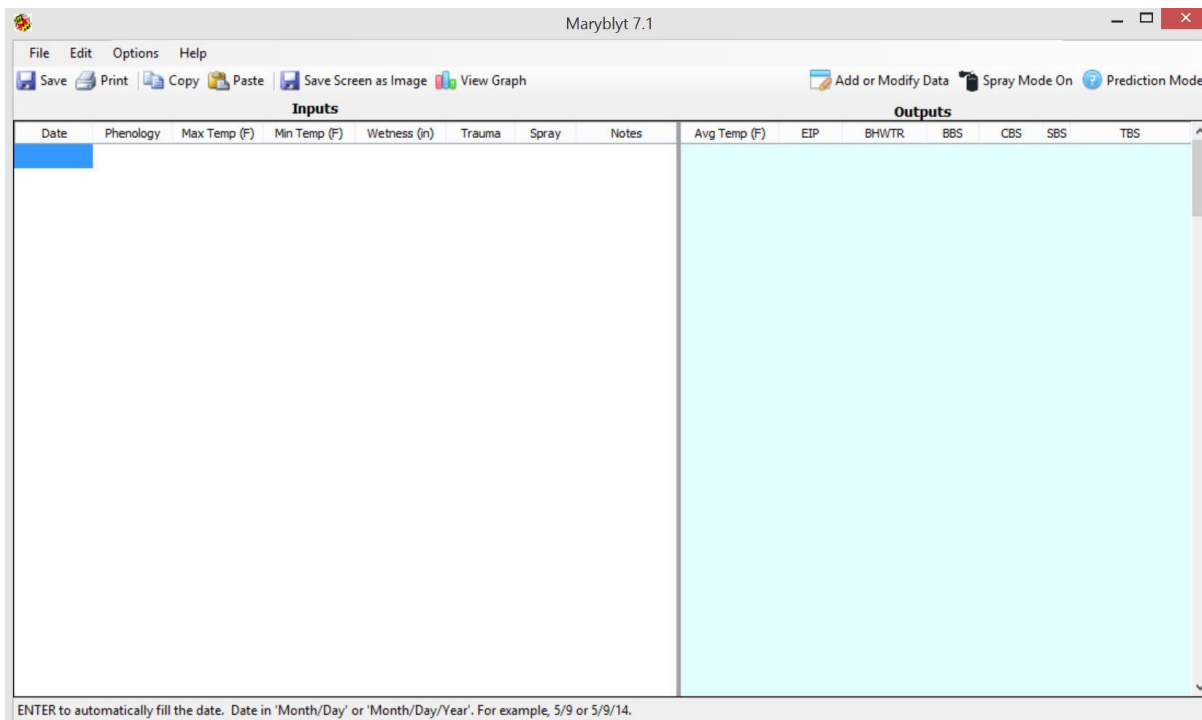
Infection Alert: ☒ On ☐ Off

Apply

Figure 5. Start a new season or Season Properties window

DOCUMENT WINDOW

The document window is displayed for a new season, or when an existing season file is opened. The document window is pictured below (Figure 6):

A screenshot of the Maryblyt 7.1 software interface. The title bar says "Maryblyt 7.1". The menu bar includes "File", "Edit", "Options", and "Help". The toolbar has icons for "Save", "Print", "Copy", "Paste", "Save Screen as Image", and "View Graph". On the right side of the toolbar are "Add or Modify Data", "Spray Mode On", and "Prediction Mode". The main window is divided into two panes. The left pane is titled "Inputs" and has columns for "Date", "Phenology", "Max Temp (F)", "Min Temp (F)", "Wetness (in)", "Trauma", "Spray", and "Notes". The right pane is titled "Outputs" and has columns for "Avg Temp (F)", "EIP", "BHWTR", "BBS", "CBS", "SBS", and "TBS". A status bar at the bottom says "ENTER to automatically fill the date. Date in 'Month/Day' or 'Month/Day/Year'. For example, 5/9 or 5/9/14.".

Maryblyt 7.1

File Edit Options Help

Save Print Copy Paste Save Screen as Image View Graph

Add or Modify Data Spray Mode On Prediction Mode

Inputs

Date	Phenology	Max Temp (F)	Min Temp (F)	Wetness (in)	Trauma	Spray	Notes

Outputs

Avg Temp (F)	EIP	BHWTR	BBS	CBS	SBS	TBS

ENTER to automatically fill the date. Date in 'Month/Day' or 'Month/Day/Year'. For example, 5/9 or 5/9/14.

Figure 6. Document Window

ENTERING DATA INTO *Maryblyt*[™] (DATA ENTRY MODE)

To enter new data or modify the existing data, press the **Add or Modify Data** button. *Maryblyt*[™] will enter “Data Entry Mode”, allowing data to be entered into the Inputs section of the spreadsheet grid shown in Figure 7. Highlight the desired cell and key in data, pressing ENTER or TAB to accept the data. Refer to the Keyboard Commands section for possible commands while entering data. After the desired data has been entered, press **Accept Changes** to accept the data or **Discard Changes** to cancel the data entry. When finished entering data, the season information must be saved. To save the file, select “Save” or “Save As” from the File menu, or press the “Save” button.

PASTING DATA FROM EXCEL

Data may also be copied and pasted from Microsoft Excel into *Maryblyt*[™]. The spreadsheet data must be ordered exactly as the *Maryblyt*[™] columns are laid out. To paste data, select a cell in the grid and paste by pressing the “Paste” button or pressing CTRL-V.

Figure 7. Data Entry Mode

Maryblyt[™] FILE FORMAT

Maryblyt[™] uses the MB7 file format. The MB7 file is a comma delimited text format resembling the following:

MB7 File Format
"Date","Phenology","Max Temp (F)","Min Temp (F)","Wetness (in)","Trauma","Spray","Notes"
"3/31/87","AG","63.0","27.0","0.13","","","FRST"


```
"4/1/87","GT","46.0","21.0","0.00","","","FRST"  
"4/2/87","GT","49.0","32.0","0.20","","",""
```

The file format is suitable for being imported into a spreadsheet program such as Microsoft Excel. Program thresholds and season information are saved to a separate file with a .props extension. These two files are saved in the same location, for example, for a season file named “MySeason”, the corresponding files are MySeason.mb7 and MySeason.mb7.props.

MAKING PREDICTIONS WITH *Maryblyt*[™] (PREDICTION MODE)

Predictions can be made at any time by pressing the **Prediction Mode** button at the top right of the Menu Bar (Figure 6). Prediction Mode cannot be accessed when you are in the Data Entry Mode (Figure 7). The simulator for making predictions is based on the use of forecasted weather information and is one of the most useful aspects of *Maryblyt*[™]. Any number of days can be entered, but most forecasts are not reliable beyond 3 days. In fact, *when critical decisions need to be made, update the predictions daily using new forecasts.*

Prediction Mode is useful for experimenting with data that is not intended to be saved. All changes made to the data while in Prediction Mode are discarded when Prediction Mode is exited. However, they can be copied and pasted (into Excel, for example) and saved for future reference. Alternatively, the screen can be saved as a photo and viewed later. Clicking the Exit Prediction Mode button will exit prediction mode and data will be lost. You can also use the PRINT function to make copies of all predictions (as data or as graphs) for later confirmation. Adjusting Spray Efficacy

ADJUSTING SPRAY EFFICACY

In *Maryblyt*[™] 7.1, users have the option of adjusting the efficacy of a chemical spray treatment. In earlier versions of *Maryblyt*[™] it was assumed that when a spray was applied that spray coverage was thorough, that all flowers open at the time of treatment were protected, and that the chemical treatment was 100% effective. But these assumptions are typically never met in practice. Users can now account for less than perfect sprays by entering an *estimate* of the actual level of efficacy and into the **Spray Effectiveness** box (Figure 8). In doing this the accumulated number of degree hours (65°C) is reduced by a factor equal to (100 - % Spray Effectiveness) and subsequent EIP calculations are reset to begin from the date of application.

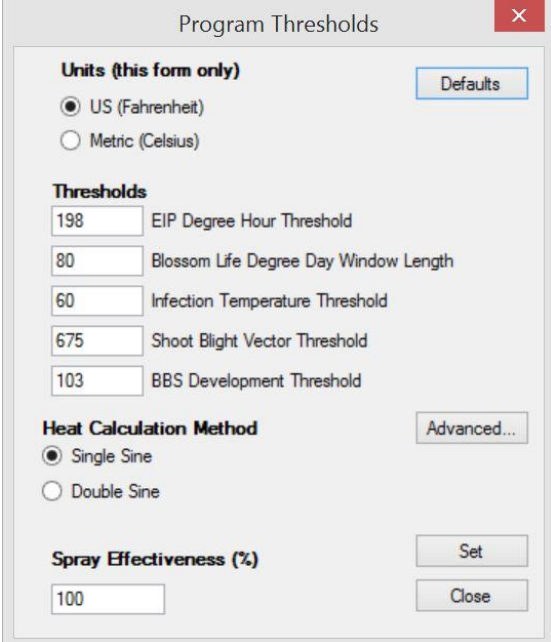
The image shows a screenshot of the 'Program Thresholds' dialog box in the Maryblyt software. The dialog has a title bar with a close button (X). Inside, there are several sections: 'Units (this form only)' with radio buttons for 'US (Fahrenheit)' (selected) and 'Metric (Celsius)', and a 'Defaults' button; 'Thresholds' with five input fields: 'EIP Degree Hour Threshold' (198), 'Blossom Life Degree Day Window Length' (80), 'Infection Temperature Threshold' (60), 'Shoot Blight Vector Threshold' (675), and 'BBS Development Threshold' (103); 'Heat Calculation Method' with radio buttons for 'Single Sine' (selected) and 'Double Sine', and an 'Advanced...' button; and 'Spray Effectiveness (%)' with an input field set to '100', a 'Set' button, and a 'Close' button.

Figure 8. Spray Effectiveness Box located in the Program Thresholds dialog window

Once a spray has been applied, the infection event (denoted as "I" under the BHWTR) will usually be downgraded to a high risk event ("H") because the EIP is often reduced to below 198. As a result, the BBS clock will not be activated. Because sprays are less than perfect it is likely that some infection may have occurred and it is of interest to initiate the BBS clock to track infection. To accomplish this, users can turn off the **Spray Mode** (Figure 6) which temporarily removes the spray to allow users to identify when blossom blight symptoms would be expected if a spray was not applied or one assumes less than 100% efficacy.

PROGRAM THRESHOLDS

Maryblyt™ uses several parameters, or program thresholds, to generate its output. These program thresholds are accessible from the **Program Thresholds** and **Advanced Thresholds** dialogs (Figures 8 & 9) under the Set Thresholds... selection of the Options menu. NOTE: Modification of these thresholds is considered advanced usage of **Maryblyt™**. To restore defaults, click DEFAULTS.

For research purposes, it is often useful to test different thresholds where data and experience suggest that the accuracy of **Maryblyt™** may be improved. To do this, select **Set Thresholds...** under the Options menu to view the current threshold values. Change a value and then click SET. For example, decreasing the **EIP Degree Hour Threshold** makes the program more conservative and may result in the identification of more infection events. Conversely, increasing the degree hour threshold may result in more unidentified infection events where significant damage might occur *in areas where fire blight is a problem*. Where fire blight is relatively rare, increasing the degree hour threshold may be one way to compensate for extremely low inoculum levels when making treatment decisions. However, a few scattered strikes may still be found when no infection event is identified using the new, higher threshold. An alternative to increasing the degree hour threshold for blossom blight is to lengthen the **Blossom Life Degree Day Window Length** which is the time period during which degree hours are accumulated prior to the reported date. Thus, increasing "blossom life" by adding 10 DD to the default value is one way of assuming a "worst case" scenario where flowers are exposed to colonization for longer periods than normally expected or if colonization occurs at a more rapid rate than usual.

The **insect vector threshold** is based on the accumulation of 675 DD > 40 °F (375 DD > 4.4 °C) from green tip when the winged adults of the white apple leafhopper (not just the immature nymphs) usually become available. This threshold can be disabled (ENTER 0) or changed to another DD > 40 °F threshold that is known for another vector. See the section (page 16) on "Identifying other insect vectors".

Advanced Threshold Changes. More advanced threshold adjustments can be made similarly by clicking the ADVANCED button in SET THRESHOLDS window. Change a value and then click SET. To restore defaults, click DEFAULTS. Values that are SET will stay changed and will not return to the default values until DEFAULTS is clicked (Figure 9).

The screenshot shows the 'Advanced Thresholds' window with various temperature and development threshold settings. The 'Units' section has 'US (Fahrenheit)' selected. The 'EIP Thresholds' section includes 'EIP Window Temperatures' (40, 90), 'EIP Temperatures' (65, 90), 'Discount Temperature' (64), 'Discount Freeze Temperature' (32), and 'Blossom Kill Temperature' (24). The 'BHWTR Thresholds' section has 'High EIP Limit' (100). The 'BBS Thresholds' section has 'BBS Temperatures' (55, 90). The 'CMS / CBS' section has 'CMS Temperatures' (55, 90), 'CBS Temperatures' (55, 90), 'CMS Development Threshold' (196), and 'CBS Development Threshold' (103). The 'SBS' section has 'Insect Vector Temperatures' (40, 90), 'SBS Temperatures' (55, 90), and 'SBS Development Threshold' (103). The 'TBS' section has 'TBS Temperatures' (55, 90) and 'TBS Development Threshold' (103). There are 'Defaults' and 'Set' buttons.

Figure 9. Advanced Program Thresholds Window

GRAPHING DATA

In addition to the spreadsheet format used for the *Maryblyt™* standard work screen,

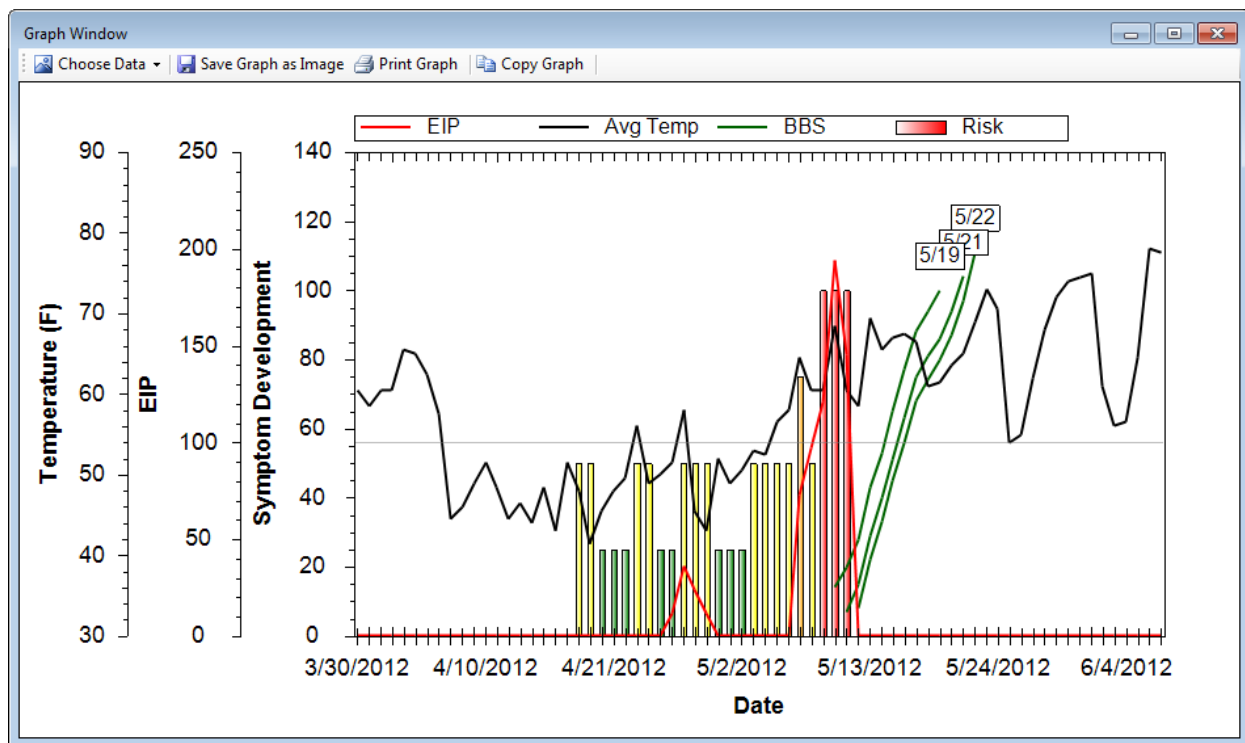


Figure 10. Example of graphical presentation of *Maryblyt™* output. Available variables are: maximum, minimum, and average temperature (shown), EIP (shown) and EIP = 100 reference line (shown), BBS (shown for three infection events), CBS, SBS, TBS, rainfall, and infection risk (shown).

the progress of various symptom predictions and a visualization of the risks for blossom infection are also presented graphically (Figure 10). To view this, Click the **View Graph** option on the Menu Bar when the data are being displayed (View Graph is “on” by default).

Up to 11 different items can be selected by clicking “Choose Data” for the **left axis**, including average temperature, EIP, and others. The **bottom axis** represents **time** as calendar days after green tip. The graph can be saved as an image, printed, or copied into the “copy/paste buffer” for pasting into other documents. Clicking “View Graph in Separate Window” places the graph in a separate Window on top of the current Window, and with the same save, print and copy functions available in the separate Window Menu Bar.

EXPLANATION OF THE DATA INPUT (LEFT) WINDOW:

The left window of the file work screen contains all the data entered by the user.

Item	Explanation
DATE	Month/Day or Month/Day/Year: The file calendar is set with the first day’s data entry; thereafter, the program will display the next date in sequence which is simply accepted by typing [RETURN] or [ENTER].
PHENOLOGY	<p>Phenological bud stage where D (=dormant) or ST (=silver tip) can be entered early but does not affect the program. Three entries are required for the program to function:</p> <p>Green tip = when 50% of the buds show green tissue, enter GT for apples or GT for pears - this is a biofix to begin predictions. You may also enter AG or PG to begin predictions.</p> <p>First bloom = when the <i>first</i> flower opens in the orchard, enter B or BL - this initiates the blossom infection risk and blossom blight symptom prediction routine; Caution: During bloom, the first character in this column <i>must</i> remain as B, the second character can be any letter or number.</p> <p>Petal fall = when the <i>last</i> open flower in an orchard is gone, enter PF or PB (post bloom) to stop blossom blight predictions.</p> <p>Any other entry in this column is for notation only and does not affect the program. The following phenological notes are suggested: TC (tight cluster), PK or WB (pink on apples, white bud on pears), BB (full bloom) and B2 (when most primary flowers are gone, but some secondary bloom remains).</p>
MAX and MIN TEMP	Maximum and minimum daily temperatures, respectively, are entered to the nearest tenth of a degree. When the minimum temperature entered is equal to or less than 28 of (-2.2°C), a frost note (Frost) is displayed in the Outputs NOTE column.

WETNESS	<p>Wetness as rain is reported to nearest 0.01 inch or 0.25 millimeter. The thoroughness of wetting is usually of greater importance than the actual quantity of rain. Thus, any heavy dew or fog that wets either foliage or flowers <i>must</i> be noted. Dew or fog events that cause wetness only on the grassy orchard floor should <i>not</i> be entered. Enter dew or fog events by TYPING DEW (or D) in the WET column in place of actual rain amounts; <i>A high volume fungicide or plant growth regulator spray during bloom (without an antibiotic) can trigger a blossom infection under some conditions.</i> If such sprays are needed TYPE 0.01 in the WET column and SPRAY in the Input Notes column. Low-volume sprays (approx. ≤ 100 gal./acre or 1,000 L/ha) are not a problem here so long as blooms are not wetted.</p>
TRAUMA	<p>This is a trauma notation. <i>Maryblyt™</i> will recognize and forecast a trauma blight situation in response to a late frost (i.e., minimum temperature) if other conditions are appropriate, but it must be informed when hail (TYPE H) or high winds (TYPE W) damage the foliage or blossoms. Entering these codes here triggers a trauma blight prediction and places a HAIL or WIND comment in the Outputs NOTES column.</p>
SPRAY	<p>TYPE S in this column <i>only</i> to inform the program that <i>an antibiotic spray is or will be applied</i>; otherwise, PRESS [RETURN] to leave blank. When the risk for blossom infection is high (H) or when an infection event (I) occurs or is predicted. When S is entered here, the cumulative degree hour clock in the program that monitors blossom colonization is reset to “zero” or to a value proportional to the spray efficacy setting (described above) so that the subsequent risks for blossom infection are based only on new flowers opening after the spray.</p>
NOTES	<p>Use for observations. Useful record notes to include here are the amount of bloom (e.g. 25%, 50%, etc.) and when early symptoms are confirmed (!) for blossom, canker, shoot and trauma blight (for example, BBS!, CBS!, SBS! and TBS!).</p>

EXPLANATION OF THE DATA OUTPUT (RIGHT) WINDOW:

The right window displays all of the risks and predictions for the *Maryblyt™* program. All reports appear immediately upon entering weather data for the day.

Item	Explanation
AVE TEMP	Simple <i>mean</i> of the daily maximum and minimum temperatures.
EIP	<p>Epiphytic Infection Potential is an index for infection risk expressed as a percent of 198 DH > 65°F (110 DH > 18.3°C) accumulated over the last 80 or 120 DD > 40°F (44.4 or 66.7 DD > 4.4°C) for apples or pears, respectively. EIP increases exponentially during warm weather and decreases in response to freezing temperatures or to cool days with no temperature exceeding 64°F (17.8°C). The maximum risk for blossom infection is based on the flowers open for the longest time or the average life [in DD > 40°F (4.4°C)] of an open flower before it petals begin to fall.</p> <p><i>The EIP is based on the assumption that abundant inoculum is available in and around the orchard. As a general rule, if the EIP is less than 100%, few, if any, infections are likely to occur; an EIP of 100-150 % is low, but is sufficient to support an epidemic of blossom blight; an EIP of more than 200-250% indicates that large numbers of infections are likely should a wetting event occur.</i></p>
BBS	<p>Blossom Blight Symptom predictions expressed as a percent of the minimum threshold for early symptoms 103 DD > 55°F or 57 DD > 12.7°C from infection date). Up to 10 separate blossom infection events can be tracked simultaneously with the BBS predictions for each labeled in sequence from “a” to “j”. When the BBS prediction for the first infection, “a”, reaches 100%, the program picks up the prediction in progress for the next event, “b”, and follows it to 100%, and so forth until all symptom events are predicted.</p>
CBS	<p>Canker Blight Symptoms predictions occur in two phases. The first is for canker margin symptoms (CMS) and is initiated when green tip (GT) is entered in the Phenology column. It is shown as a percent of the minimum threshold for this event (CMS = 100% = 196 DD > 55°F, or 109 DD > 12.7°C after green tip).</p> <p>When the CMS threshold is met, a second sequence begins again at zero to predict the appearance of the more visible canker blight symptoms (CBS = 100% = 299 DD > 55°F, or 166 DD > 4.4°C after green tip).</p> <p>These events occur regularly every year where cankers are present, even when blossom infections do not occur and provide a source of inoculum for shoot blight.</p>
SBS	<p>Shoot Blight Symptom predictions are shown as a percent of a variable minimum threshold (SBS = 100%) determined by the time that either BBS</p>

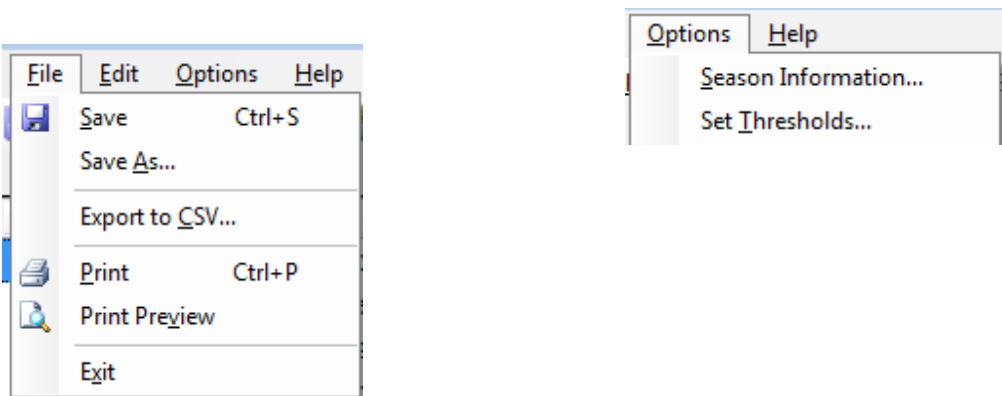
	or CBS appear and when the insect vector threshold (default for white apple leafhopper adults = 675 DD > 40°F or 375 DD > 4.4°C after green tip) is met. Using Options/Set Thresholds to change this vector threshold if another vector is known. <i>Maryblyt</i> [™] predicts only the first early shoot blight event although there are likely to be others throughout the period of active shoot growth. This prediction is made on the assumption that suitable insect vectors are present; first symptoms may be delayed beyond the predicted date where insects are not present or are well controlled.
TBS	Trauma Blight Symptom predictions are triggered when over 198 DH > 65°F (110 DH > 18.3°C) accumulate and severe trauma events such as late frosts (< 28°F or 2.2°C), hail storms or high winds damage the foliage. Up to 10 separate trauma blight incidents can be tracked simultaneously and each is labeled in sequence from “a” to “j”.
NOTES	The <i>Maryblyt</i> [™] program inserts notes here when DEW (or D), FOG (or F) is entered in the WET column, when a frost (Frost) occurs, or when H (HAIL) or W (WIND) is entered in the Trauma column.

SUMMARY OF *Maryblyt*[™] KEYBOARD, DROPDOWN MENU AND TOOLBAR COMMAND OPTIONS

Keyboard Commands


Keyboard Command	Description
Arrow Keys (Up/Down/Left/Right)	Move to the adjacent cell. Holding Shift while moving will allow selection of multiple cells
HOME	Move to the first row.
END	Move to the last row containing data.
ENTER	Accept input in the current cell and move to the next cell. Pressing ENTER in the DATE column will automatically fill in the next record's date or the current date if it is the first row.
TAB	Accept input in the current cell and moves to the next cell
F2	Edit the existing information in the current cell.
DEL/Backspace	Clear the data from the selected cells.
CTRL-C	Copy data from selected cells to the Windows Clipboard
CTRL-V	Paste copied data into grid, starting at selected cell.
CTRL-A	Select all cells.

Program Menu Commands



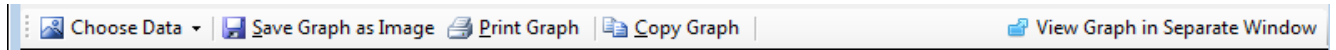
Menu Command	Description
FILE MENU	
Save/Save As	Saves the current data to a <i>Maryblyt</i> [™] file (*.mb7).
Print/Print Preview	Prints the grid data.
Export to CSV...	Exports all data in the grid to a comma-delimited text file.
OPTIONS MENU	
Season Information...	Shows the Season Information dialog.
Set Thresholds...	Shows the Program Thresholds dialog, allowing thresholds to be changed. Refer to the Program Thresholds section for details on changing program thresholds.

Main Toolbar Commands



Toolbar Command	Description
Save Screen As Image	Saves a screen capture of the document window to an image file.
View Graph	Shows or hides the graph pane from the bottom of the document window.
Add or Modify Data	Enters “Data Entry Mode”, allowing data to be input into the grid.
Spray Mode On/Off	Allows users to control whether or not <i>Maryblyt</i> [™] adjusts EIP when a spray is applied. Useful for determining when symptoms could occur if control measures had not been implemented.
Prediction Mode	Enters “Prediction Mode”, allowing data to be input into the grid. Any changes to data are discarded when Prediction Mode is exited.

Graph Toolbar Commands



Graph Toolbar Command	Description
Choose Data	Selects graph items to be displayed.
Save Graph as Image	Saves a picture of the graph to an image file.
Copy Graph	Copies an image of the graph to the Windows clipboard. The copied image can be pasted in another application such as a word processing program or image editing program.
View Graph in Separate Window	Shows the graph in a separate window that can be maximized or resized.

EXAMPLE USE OF *Maryblyt*[™]

Enter the following data (be sure to enter the **Add or Modify Data** mode):

Maryblyt 7.1 C:\Users\Alan R. Biggs\Documents\Maryblyt Data Files\MB-2012\2012TestFile.mb7

File Edit Options Help

Save Print Copy Paste Save Screen as Image View Graph Add or Modify Data Spray Mode On Prediction Mode

Inputs								Outputs						
Date	Phenology	Max Temp	Min Temp	Wetness (in)	Trauma	Spray	Notes	Avg Temp (F)	EIP	BHWTR	BBS	CBS	SBS	TBS
3/14/...	GT	80.0	66.0	0.00				73.0	-	-	-	9	-	-
3/15/...	GT	79.6	43.7	0.00				61.6	-	-	-	14	-	-
3/16/...	TC	68.5	48.3	0.06				58.4	-	-	-	16	-	-
3/17/...	TC	75.1	45.9	0.00				60.5	-	-	-	20	-	-
3/18/...	TC	65.1	52.8	0.00				59.0	-	-	-	22	-	-
3/19/...	TC	73.9	50.5	0.08				62.2	-	-	-	27	-	-
3/20/...	PK	72.2	54.3	0.01				63.2	-	-	-	31	-	-
3/21/...	PK	65.8	49.0	0.01				57.4	-	-	-	33	-	-
3/22/...	PK	76.1	54.5	0.00				65.3	-	-	-	38	-	-
3/23/...	B1	75.0	52.5	0.00				63.8	36	+ - - + M	-	42	-	-

Having exited the **Add or Modify Data** function above, click **Prediction Mode** to demonstrate the simulator in *Maryblyt*[™], which uses forecasted weather information to make predictions. When the cells appear, enter the forecasted weather data in the cells in the **Inputs** screen (i.e., the data from 3/24-28). The simulated data appears normally in the cells following their entry.

Maryblyt 7.1 C:\Users\Alan R. Biggs\Documents\Maryblyt Data Files\MB-2012\2012TestFile.mb7

File Edit Options Help

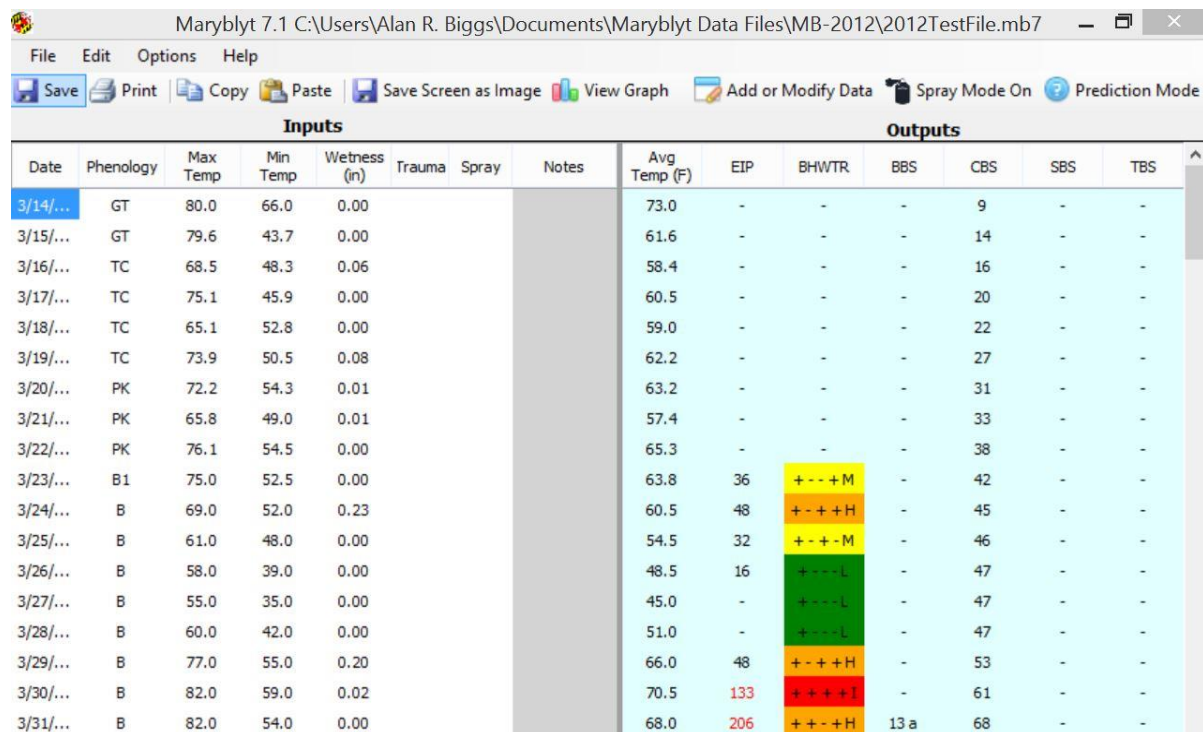
Save Print Copy Paste Save Screen as Image View Graph Exit Prediction Mode

Inputs								Outputs						
Date	Phenology	Max Temp	Min Temp	Wetness (in)	Trauma	Spray	Notes	Avg Temp (F)	EIP	BHWTR	BBS	CBS	SBS	TBS
3/14/...	GT	80.0	66.0	0.00				73.0	-	-	-	9	-	-
3/15/...	GT	79.6	43.7	0.00				61.6	-	-	-	14	-	-
3/16/...	TC	68.5	48.3	0.06				58.4	-	-	-	16	-	-
3/17/...	TC	75.1	45.9	0.00				60.5	-	-	-	20	-	-
3/18/...	TC	65.1	52.8	0.00				59.0	-	-	-	22	-	-
3/19/...	TC	73.9	50.5	0.08				62.2	-	-	-	27	-	-
3/20/...	PK	72.2	54.3	0.01				63.2	-	-	-	31	-	-
3/21/...	PK	65.8	49.0	0.01				57.4	-	-	-	33	-	-
3/22/...	PK	76.1	54.5	0.00				65.3	-	-	-	38	-	-
3/23/...	B1	75.0	52.5	0.00				63.8	36	+ - - + M	-	42	-	-
3/24/...	B	69.0	52.0	0.23				60.5	48	+ - - + H	-	45	-	-
3/25/...	B	61.0	48.0	0.00				54.5	32	+ - - + M	-	46	-	-
3/26/...	B	58.0	39.0	0.00				48.5	16	+ - - + L	-	47	-	-
3/27/...	B	55.0	35.0	0.00				45.0	-	+ - - + L	-	47	-	-
3/28/...	B	60.0	42.0	0.00				51.0	-	+ - - + L	-	47	-	-

The risks and predictions expected as a result of the forecasted weather information appear in the right (**Outputs**) window. Treatment decisions should be based on the current risks in the orchard shown at and prior to the current date in the BHWTR column AND the simulated or potential risks shown in the prediction mode in the BHWTR column.

Decision making. The screen capture above shows the current status in the orchard just after the start of bloom with only a **Moderate** risk of infection occurring on March 23. After entering the 5-day forecast for March 24 – 28 using **Prediction Mode**, the BHWTR column shows that *if the weather forecast is accurate* (user's judgment required), then March 24 will be a **High** risk day [i.e., all but one required factor (EIP) is present]. In this case, the **EIP** will be *below* the threshold for infection (i.e., <100%) and the subsequent cool weather expected for March 25 - 28 will reduce the EIP and infection risks even more. Given this, even though High Risk appears in the BHWTR column for March 24, *the most appropriate decision here is to delay applying the spray* until the conditions for infection develop later.

Click **Exit Prediction Mode** to exit the forecasting function above. Move the cursor to the line following the last days data entry using the ↓ arrow, then Click [Return or Enter] to begin adding more data. **Add** the data at the top that we used for the forecast for **March 24 through March 28**. Next **add** data for March 29 - 31, as shown below, and observe that High blossom infection risk occurs on March 29, and an **Infection** event is expected for March 30.



The screenshot shows the Maryblyt 7.1 software interface. The title bar indicates the file path: C:\Users\Alan R. Biggs\Documents\Maryblyt Data Files\MB-2012\2012TestFile.mb7. The menu bar includes File, Edit, Options, and Help. The toolbar contains icons for Save, Print, Copy, Paste, Save Screen as Image, View Graph, Add or Modify Data, Spray Mode On, and Prediction Mode. The main window is divided into two sections: Inputs and Outputs.

Inputs								Outputs						
Date	Phenology	Max Temp	Min Temp	Wetness (in)	Trauma	Spray	Notes	Avg Temp (F)	EIP	BHWTR	BBS	CBS	SBS	TBS
3/14/...	GT	80.0	66.0	0.00				73.0	-	-	-	9	-	-
3/15/...	GT	79.6	43.7	0.00				61.6	-	-	-	14	-	-
3/16/...	TC	68.5	48.3	0.06				58.4	-	-	-	16	-	-
3/17/...	TC	75.1	45.9	0.00				60.5	-	-	-	20	-	-
3/18/...	TC	65.1	52.8	0.00				59.0	-	-	-	22	-	-
3/19/...	TC	73.9	50.5	0.08				62.2	-	-	-	27	-	-
3/20/...	PK	72.2	54.3	0.01				63.2	-	-	-	31	-	-
3/21/...	PK	65.8	49.0	0.01				57.4	-	-	-	33	-	-
3/22/...	PK	76.1	54.5	0.00				65.3	-	-	-	38	-	-
3/23/...	B1	75.0	52.5	0.00				63.8	36	+ - - + M	-	42	-	-
3/24/...	B	69.0	52.0	0.23				60.5	48	+ - - + H	-	45	-	-
3/25/...	B	61.0	48.0	0.00				54.5	32	+ - - + M	-	46	-	-
3/26/...	B	58.0	39.0	0.00				48.5	16	+ - - + L	-	47	-	-
3/27/...	B	55.0	35.0	0.00				45.0	-	+ - - + L	-	47	-	-
3/28/...	B	60.0	42.0	0.00				51.0	-	+ - - + L	-	47	-	-
3/29/...	B	77.0	55.0	0.20				66.0	48	+ - - + H	-	53	-	-
3/30/...	B	82.0	59.0	0.02				70.5	133	+ + + + I	-	61	-	-
3/31/...	B	82.0	54.0	0.00				68.0	206	+ + - + H	13 a	68	-	-

Now exit the **Add or Modify Data** mode by clicking **Accept Changes**. Leave the **Spray** column blank at this time.

Decision making. Antibiotic sprays work best when applied just before infection. Thus, *making a spray application on 3/29 would be a good decision*. On 3/30, the red bar in the BHWTR column and the "I" indicate that conditions exist for blossom infection. In response to the apparent infection on 3/30, a prediction for blossom blight symptoms (BBS) begins on 3/31 as **13a**, indicating that progress towards the first appearance of symptoms for the first infection will be 13% complete.

Next, we are going to note that adding spraying decisions in the **Spray** column on 3/29 will affect the model's Output functions.

Click **Add or Modify Data** and using the cursor or arrow keys move to the 3/29 date and edit the line. Press Return or Enter repeatedly until you get to the Spray column and type in "Yes" (no quotes) and Return or Enter again. This "informs" the program that an antibiotic spray was applied on 3/29 (with 100% efficacy). Note that the EIP value is "reset" to zero (represented as a "-") and that the risks now reported are based on colonization of flowers opening after the spray was applied.

Maryblyt 7.1 C:\Users\Alan R. Biggs\Documents\Maryblyt Data Files\MB-2012\2012TestFile.mb7

File Edit Options Help

Save Print Copy Paste Save Screen as Image View Graph

Accept Changes Discard Changes

Inputs

Data Entry Mode

Outputs

Date	Phenology	Max Temp (F)	Min Temp (F)	Wetness (in)	Trauma	Spray	Notes	Avg Temp (F)	EIP	BHWTR	BBS	CBS	SBS	TBS
3/14/...	GT	80.0	66.0	0.00				73.0	-	-	-	9	-	-
3/15/...	GT	79.6	43.7	0.00				61.6	-	-	-	14	-	-
3/16/...	TC	68.5	48.3	0.06				58.4	-	-	-	16	-	-
3/17/...	TC	75.1	45.9	0.00				60.5	-	-	-	20	-	-
3/18/...	TC	65.1	52.8	0.00				59.0	-	-	-	22	-	-
3/19/...	TC	73.9	50.5	0.08				62.2	-	-	-	27	-	-
3/20/...	PK	72.2	54.3	0.01				63.2	-	-	-	31	-	-
3/21/...	PK	65.8	49.0	0.01				57.4	-	-	-	33	-	-
3/22/...	PK	76.1	54.5	0.00				65.3	-	-	-	38	-	-
3/23/...	B1	75.0	52.5	0.00				63.8	36	+++M	-	42	-	-
3/24/...	B	69.0	52.0	0.23				60.5	48	+++H	-	45	-	-
3/25/...	B	61.0	48.0	0.00				54.5	32	+++M	-	46	-	-
3/26/...	B	58.0	39.0	0.00				48.5	16	+++L	-	47	-	-
3/27/...	B	55.0	35.0	0.00				45.0	-	+++L	-	47	-	-
3/28/...	B	60.0	42.0	0.00				51.0	-	+++L	-	47	-	-
3/29/...	B	77.0	55.0	0.20		Yes		66.0	-	+++H	-	53	-	-
3/30/...	B	82.0	59.0	0.02				70.5	85	+++H	-	61	-	-
3/31/...	B	82.0	54.0	0.00				68.0	158	+++H	-	68	-	-

For the next example, go back and undo the addition of the "Yes" to the **Spray** column and then **Add or Modify Data** to include the remaining data for 4/1 through 4/24 from the figure shown below. **On 4/3**, a second infection event, "b", occurs in response to 0.80 inch rain. Since this is more than 0.1 inch, an infection event is also triggered for the following day, 4/4. Here, *a single spray on 4/2 should be adequate for both of these infection events.*

On 4/8, symptoms for the first infection event, "a" (3/30) reach the 100 % threshold (BBS! added to the Notes column; a "-BBS" note added by the user on 4/8 would indicate that blossom blight symptoms were *not* found on the date predicted and would suggest that the spray made on 3/29 was effective.

On 4/9, the symptom prediction in progress for infection event "b" is reported as 83% complete and was confirmed **on 4/11** (the user should make a BBS! notation in the Note column). This is a good opportunity to assess spray coverage since scattered infections in tree tops and centers may indicate the sprayer is not covering blossoms well. This may be related to excessive travel

speed, faulty nozzle arrangement, or spraying under windy conditions.

Maryblyt 7.1 C:\Users\Alan R. Biggs\Documents\Maryblyt Data Files\MB-2012\2012TestFile.mb7

File Edit Options Help

Save Print Copy Paste Save Screen as Image View Graph Accept Changes Discard Changes

Inputs **Data Entry Mode** **Outputs**

Date	Phenology	Max Temp (F)	Min Temp (F)	Wetness (in)	Trauma	Spray	Notes	Avg Temp (F)	EIP	BHWTR	BBS	CBS	SBS	TBS
4/1/...	B	62.0	49.0	Dew			Dew	55.5	105	+++H	15 a	69	-	-
4/2/...	B	72.0	64.0	0.00				68.0	141	+++H	27 a	76	-	-
4/3/...	B	78.0	63.0	0.80				70.5	158	++++I	43 a	84	-	-
4/4/...	B	74.0	60.0	0.00				67.0	145	++++I	54 a	90	-	-
4/5/...	B	75.0	59.0	0.00				67.0	158	+++H	66 a	96	-	-
4/6/...	B	81.0	63.0	0.00				72.0	170	+++H	83 a	CMS	-	-
4/7/...	PF	80.0	65.0	0.00			BBS!	72.5	-	-	100 a	17	-	-
4/8/...	PB	75.0	59.0	0.00				67.0	-	-	69 b	29	-	-
4/9/...	PB	78.0	62.0	0.00				70.0	-	-	83 b	44	-	-
4/10/...	PB	78.0	64.0	0.00				71.0	-	-	99 b	59	-	-
4/11/...	PB	76.0	60.0	0.00				68.0	-	-	112 b	72	-	-
4/12/...	PB	72.0	58.0	1.03				65.0	-	-	-	82	10	-
4/13/...	PB	79.0	64.0	0.50			CBS!	71.5	-	-	-	97	25	-
4/14/...	PB	82.0	70.0	0.00				76.0	-	-	-	CBS	46	-
4/15/...	PB	79.0	62.0	0.00				70.5	-	-	-	-	61	-
4/16/...	PB	81.0	65.0	0.10			SBS!	73.0	-	-	-	-	79	-
4/17/...	PB	91.0	61.0	1.25	Hail		Hail	76.0	-	-	-	-	99	-
4/18/...	PB	88.0	60.0	0.00				74.0	-	-	-	-	117	18 a
4/19/...	PB	82.0	61.0	0.00				71.5	-	-	-	-	-	34 a
4/20/...	PB	78.0	58.0	0.00				68.0	-	-	-	-	-	47 a
4/21/...	PB	80.0	52.0	0.00				66.0	-	-	-	-	-	57 a
4/22/...	PB	79.0	58.0	0.10				68.5	-	-	-	-	-	71 a
4/23/...	PB	76.0	59.0	0.00				67.5	-	-	-	-	-	83 a
4/24/...	PB	75.0	61.0	0.20			TBS!	68.0	-	-	-	-	-	95 a
4/25/...	PB	78.0	58.0	0.00				68.0	-	-	-	-	-	108 a

H = Hail, W = High Wind, F = Frost. DEL or Backspace to clear.

Do not ignore the warning for canker blight symptoms (=CBS) shown on 4/14. In the absence of significant blossom blight, active overwintering cankers provide an inoculum source for the bacteria to be moved by insects, rain, and wind to susceptible shoot tips. Locate these first CBS symptoms early and remove all cankers and nearby infected shoots completely.

On 4/17, a trauma event occurred as hail. Entering **H** in the **Trauma** column on 4/17 when hail was observed triggers a forecast for trauma blight symptoms (see TBS! on 4/24).

ADDITIONAL SUGGESTIONS WHEN FORECASTING

When to Start and Stop Data Entry: Begin data entry for *Maryblyt*™ just *before* green tip is expected [i.e., list **D** (=dormant) or **S**(ilver)**T**(ip) in the **Phenology** column]. DO NOT STOP entering daily weather data until *at least* the prediction of early shoot blight symptoms (**SBS** ≥ 100) or until the last trauma blight symptom (**TBS** ≥ 100) if a trauma event (hail or high wind) occurred. See the above comments for **Phenology** data entry on when to enter

the three critical bud stages of green tip, first bloom and petal fall. During the early season, before bloom, data can be entered every few days or weekly; once bloom is about to start and when forecasts predict that an infection event or symptom appearance is near, data entries (and decisions!) should be made daily.

Prediction Mode: Use *this feature often!* Daily entries to the file show the current status in the orchard. Entries under Prediction Mode allow the user to *simulate* what is likely to happen over the next few days based on forecasted weather. Using the information developed in *both* real time *and* in simulated time provides the best basis for disease management decisions.

When predicted weather suggests that the risks for blossom infection will be moderate to high, it is sometimes very useful to *repeat a simulation* using temperature or rainfall data that is MORE than forecast in order to establish the *range* of conditions necessary for infections to occur in the next 1-3 days. For example, what happens when the forecasted minimum and maximum temperatures are increased by 3 degrees? Add a rain? Remove a rain? This can provide an estimated degree of "safety" should the weather develop differently than was forecast. This tactic is most useful where local weather forecasts are unreliable or naturally tend to change frequently.

Do not restrict decision making only to the application of antibiotic sprays for blossom blight. Predictions on symptom and vector appearance also demand action such as cutting out active infections and applying insecticides. Knowing when these events are most likely to occur aids in timing these steps to have the greatest effect on reducing the potential for new infections.

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