Evaluation of the Computer Model MARYBLYT for Predicting Fire Blight Blossom Infection on Apple in Michigan

A. L. JONES, Department of Botany and Plant Pathology and Pesticide Research Center, Michigan State University, East Lansing 48824

ABSTRACT

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MARYBLYT was evaluated for predicting fire blight blossom infections using weather data and observations made over four growing seasons in several apple (*Malus domestica*) orchards in Michigan. The model was more accurate in predicting the appearance of symptoms than in predicting infection periods. It accurately predicted that the weather was unfavorable for infection of flowers in 1983 and 1990 and highly favorable for infection of flowers in 1991. Four infection periods were predicted in 1984, but no or very little fire blight blossom infection was observed. The model predicted that fire blight in 1990 was associated with injury to blossoms and leaves from high winds (trauma blight) rather than to normal blossom infection. Parts of the model are subjective, and some modifications in the software would improve the model's usefulness to users unfamiliar with fire blight and its prediction. Despite limitations, the model is a valuable tool for focusing the attention of growers, extension personnel, and researchers on factors known to influence the disease and how those factors can interact to result in infection and the development of fire blight symptoms.

Additional keywords: *Erwinia amylovora*

Prediction of fire blight on blossoms of apple and pear by the fire blight pathogen *Erwinia amylovora* (Burrill) Winslow et al has been the subject of research studies dating back to the early 1950s. In New York State, outbreaks of infection during the blossom stage were related to daily maximum temperatures of 18 C or above when accompanied by precipitation or high relative humidity (6,7). In Illinois, blossom infections were related to the accumulation of a minimum of 16.5 degree days above 18 C since the last frost and early bloom along with maximum temperatures between 18 and 30 C with light rain or high humidity during early bloom (9). In California, infection was related to epiphytic populations of *E. amylovora* on pear blossoms (15), which in turn were related to daily mean temperatures above a line drawn from 16.7 C on 1 March to 14.4 C on 1 May (16). In England, outbreaks of fire blight were related to the temperature required for doubling of the pathogen and rain (1,2). This system, known as the Billing system, was used extensively to evaluate the potential risk for fire blight in several countries in Europe. In the mid-Atlantic states, a comprehensive computer model (MARYBLYT) was developed to determine infection periods and predict symptom development (5,12,13). The model requires daily temperature, rainfall, and tree phenology data.

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In Michigan, outbreaks of fire blight on apple (*Malus domestica* Borkh.) are sporadic. To protect against unexpected outbreaks, some growers apply the antibiotic streptomycin several times each season without considering whether or not the environmental conditions are favorable for infection. Recently, streptomycin-resistant *E. amylovora* was detected in one of these orchards (3) and streptomycin-resistant strains of other gram-negative bacteria were detected in sprayed orchards in New York (8) and Michigan (11). Lowering the selection pressure of streptomycin on populations of bacteria by reducing the number of applications of the antibiotic to control fire blight may help delay the buildup of resistant strains. A potential benefit of the MARYBLYT model is eliminating unnecessary sprays for fire blight by improving the timing of sprays (12).

The objective of this study was to establish the applicability of the MARYBLYT model for predicting outbreaks of blossom blight on apple in Michigan.

MATERIALS AND METHODS

MARYBLYT version 3.0 was provided by P. W. Steiner of the University of Maryland, College Park. It has been distributed to a limited number of scientists and extension specialists for evaluation before the final version is released for general distribution. The model was evaluated using historical data from the 1983 and 1984 growing seasons and current data from the 1990 and 1991 growing seasons.

Study sites. Apple orchards with fire blight infections in 1982 were selected for study in 1983. They were located in southwest (orchards 1 and 2), central (orchards 3 and 4), and west central (orchard 5) Michigan. The cultivars in each orchard were highly susceptible to fire blight, and trees ranged in age from 6 to 30 yr. In 1984, one orchard in each of the three regions was studied. In 1990, studies were conducted in a Jonathan orchard near East Lansing. In 1991, Jonathan orchards (24 and 21 yr old, respectively) near Eau Claire and East Lansing were studied.

Detection of *E. amylovora*. Twenty blossoms were collected at periodic intervals from each of 10 trees per block in 1983 and 1984. Samples were held on ice in plastic bags in a cooler until later in the day. Each sample of 200 blossoms was placed in a 2-L flask and washed with 100 ml of distilled water for 1 min. Populations of *E. amylovora* were determined by dilution plating as described previously (14), except that CCT medium (4) was used as the semiselective isolation medium. Colonies of *E. amylovora* were identified by their distinctive light purple, opalescent color with a faint purplish center on CCT medium and by pathogenicity tests on seedlings of the apple cultivar Jonathan (10).

Fire blight forecasts. Temperature and rainfall data were collected in each orchard, except in East Lansing in 1991, with a RSS-411 or RSS-412 apple scab predictor (Reuter-Stokes, Inc., Cleveland, OH). Weather data at East Lansing in 1991 were collected with an EnviroCaster (Neogen Corp., Lansing, MI). Blossom blight infection periods were identified and symptom development was predicted in all four seasons from temperature, rainfall, and phenology data using MARYBLYT version 3.0 (5,12) and a personal computer (Ocean Interface Co., Walnut, CA). The index of relative epiphytic inoculum potential (EIP) computed by the MARYBLYT model was compared with the recovery of *E. amylovora* from flowers in 1983 and 1984. Graphs of the average daily temperature and predicted progress of infections to symptom appearance were printed after transferring graphic displays from

Table 1. Description of apple orchards in Michigan, results of monitoring blossoms for epiphytic *Erwinia amylovora*, and comparison of MARYBLYT predicted with observed fire blight blossom infection

Year	Orchards: Code no.	Orchards: Location	Orchards: Age (yr)	Orchards: Cultivar	Blossom sampling dates	Respective EIP values[a]	Bacteria detected	Date symptoms expected: Predicted	Date symptoms expected: Observed
1983	1	Lawrence	25–30	Jonathan	4, 6, 11 May	0, 0, 0	No		
					17, 20, 25 May	30, 42, 59	Yes	None	None
	2	Bangor	10	Jonathan	4, 6, 11 May	0, 0, 0	No		
					17, 20, 25 May	0, 22, 54	Yes	None	None
	3	Sparta	25–30	Idared	4, 11, 17, 20 May	0, 0, 0, 0	No		
					24, 28 May, 1 June	12, 30, 9	Yes	None	15 June[b]
	4	Belding	25–30	Jonathan	4, 11, 17 May	0, 0, 0	No		
					20, 24, 27 May	14, 44, 0	Yes	None	15 June
	5	East Lansing	6	Jonathan	5, 11, 18 May	0, 0, 3	No		
					20, 24, 28 May	18, 80, 125	Yes	None	15 June
1984	4	Belding	25–30	Jonathan	17, 21 May	0, 97	No		
					25, 29 May	176, 40	Yes	5 June	None
	5	East Lansing	8	McIntosh	19 May	115	No		
					21, 25, 29 May	158, 333, 76	Yes	3 June	4 June
	6	Coloma	6	Rome Beauty	14, 19 May	0, 127	No		
					21, 25, 29 May	173, 186, 44	Yes	3 June	None

[a] EIP = relative epiphytic inoculum potential computed by MARYBLYT.
[b] None to 10 blossom blight strikes per orchard were detected in orchards 3, 4, and 5 in 1983. Blight symptoms were first noted on 4 June 1984 in orchard 5; there were 49.4 strikes on one tree on 11 June and zero to four strikes per tree on adjacent trees.

MARYBLYT to the software program Paintbrush (Microsoft Corporation, Redmond, WA). The original graphs were modified by removing progress lines for canker and shoot infections and by inserting labels.

RESULTS

1983. Sampling for *E. amylovora* was initiated before the flowers opened, but the bacteria were not detected in blossom samples until after the flowers opened. The first confirmed detection of *E. amylovora* was on 5 May in orchard 5, on 17 May in orchard 1, on 10 May in orchards 2 and 4, and on 24 May in orchard 3 (Table 1). Once detected, the bacteria were recovered regularly from flowers until petal fall. Predicted EIP values from MARYBLYT did not exceed the relative threshold of 100 in any orchard except orchard 5. No blossom blight infection was predicted on the basis of weather data collected in each orchard. Trace amounts of fire blight were observed in orchards 3, 4, and 5; none was observed in orchards 1 and 2 during a 1-mo period after petal fall.

1984. *E. amylovora* was first recovered from flowers collected on 21 May in orchards 5 and 6 and on 25 May in orchard 4 (Table 1). First recovery of bacteria coincided with predicted EIP values over 100 on a relative scale. Blossom blight infection was predicted from weather data collected on 4 days during the bloom period (Fig. 1). In orchard 5, a few blighted spurs were observed on 4 June, 1 day after symptoms were predicted to appear. Although the model had predicted that blossom blight infection should occur in orchards 4 and 6, and *E. amylovora* was detected in flowers collected from each orchard, no fire blight symptoms were observed in these orchards.

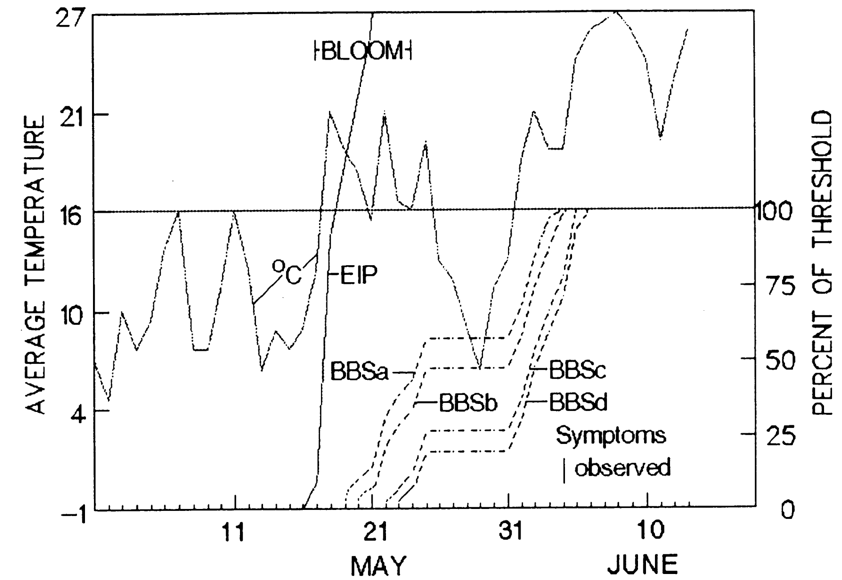

Fig. 1. Relative epiphytic inoculum potential (EIP) and anticipated symptom development for fire blight blossom infections (BBS) predicted by the MARYBLYT model based on average daily temperature, rainfall (not shown), and phenology data collected in an apple orchard (orchard 5) near East Lansing, Michigan, in 1984. Similar predictions were made from data collected in orchards 4 and 6 (Table 1), but no fire blight infections were observed in these orchards.

1990. No infection periods were predicted during the bloom period because temperatures were lower than 16 C through most of the period (Fig. 2). Severe winds on 9 May forcibly removed the petals from most of the flowers. Rain on the morning of 10 May was followed by low temperatures. The trauma blight feature in the MARYBLYT model was initiated on 9 May. Fire blight was first observed in the orchard on 6 June, 1 day after symptoms of fire blight were predicted to appear. There was an accumulation of 53 degree days above 12.7 C in the 28-day interval between infection on 9 May and predicted trauma blight symptoms on 6 June.

1991. A high incidence of blossom blight was observed in each orchard in 1991. In the orchard at Eau Claire, 11–20 infected spurs per tree were evident on 23 May, and the severity of fire blight continued to increase until all trees in the orchard showed severe infection. The severity of fire blight in this orchard was typical for Jonathan blocks in a two-county region of southwest Michigan. Blossom blight was also severe in orchards near East Lansing, but less so than in the Eau Claire region.

In Eau Claire, blossom blight infection was predicted during early bloom on 30 April and a second infection period was predicted on 10 May, just before petal

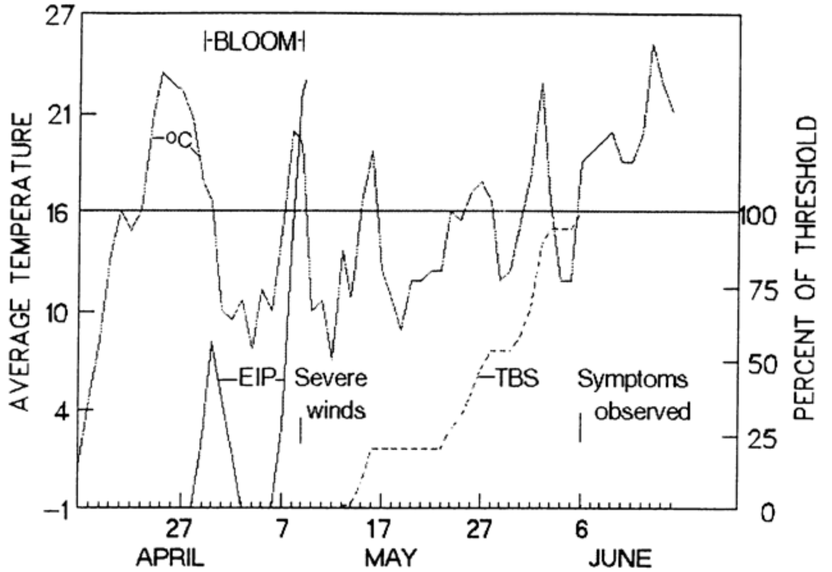

Fig. 2. Anticipated symptom development for fire blight trauma infections (TBS) associated with severe wind on 9 May as predicted by the MARYBLYT model from average daily temperature data collected in a Jonathan apple orchard near East Lansing, Michigan, in 1990. EIP = relative epiphytic inoculum potential.

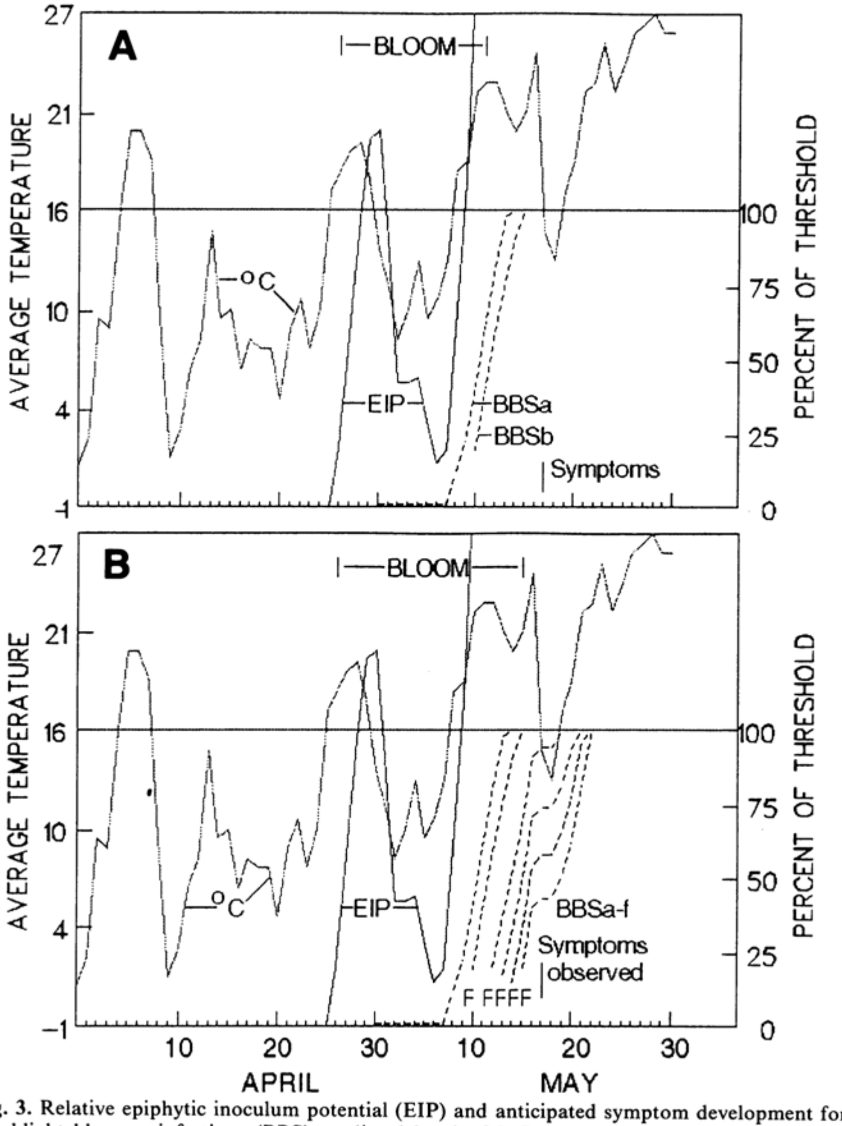

Fig. 3. Relative epiphytic inoculum potential (EIP) and anticipated symptom development for fire blight blossom infections (BBS) predicted by the MARYBLYT model based on average daily temperature, rainfall (not shown), and phenology data collected in a Jonathan apple orchard near Eau Claire, Michigan, in 1991. Petal fall was **(A)** on 12 May or **(B)** extended to 15 May, to account for late blooms. F = morning fog.

fall (Fig. 3). Symptoms were predicted to appear on 14 and 15 May and were evident when the orchard was visited on 17 May. Although most of the flowers were in petal fall on 10 May, there was a significant amount of late bloom. No rain was recorded from 11 to 15 May, but morning fogs were recorded by an observer for the National Weather Bureau on 12–15 May. Multiple infection periods were predicted when the bloom period was extended and fog was indicated as rain (Fig. 3).

The weather in East Lansing was similar to that in Eau Claire, but daily temperatures in East Lansing were slightly lower and the onset of bloom was delayed by 3 days. Blossom blight infection was predicted during late bloom on 12 May, and a second infection period was predicted on 13 May when the bloom period was extended and fog was indicated as 0.3 mm rain (Fig. 4). Symptoms were predicted to appear on 21 and 22 May and were evident on 23 May.

DISCUSSION

This study is an independent evaluation of the MARYBLYT model for predicting apple fire blight. Previous studies on MARYBLYT involved developing the model empirically, and when predictions did not agree with available observations, underlying values in the model were adjusted (6,12,13). My evaluation differs in that the model was not modified during the course of the study. The study emphasized the blossom blight stage, and I did not evaluate the canker and shoot blight stages.

The model was quite accurate in predicting the appearance of blossom blight symptoms. An accumulation of 50 degree days above 12.7 C was used to determine the interval between the onset of infection and the first symptom appearance (12). Blossom blight was observed 1–2 days after the symptoms were predicted to occur. When orchards were visited a few days after the predicted date, symptoms were well developed, indicating that infections were probably visible about as predicted.

The model was less accurate in predicting infection periods than in predicting the appearance of blossom blight symptoms. Infection was predicted four times during the bloom period of 1984, but either symptoms failed to develop or the severity of infection was light (Fig. 1, Table 1). Infection was not limited by lack of inoculum because bacteria were recovered from blossom samples collected in each of the three orchards (Table 1). In California, pear flowers can develop resistance to infection (15), and a similar phenomenon may have occurred on apple flowers in Michigan in 1984. Although blossom blight was not always observed after predictions of infection by the MARYBLYT program, occasional false predictions should be acceptable to apple growers. This is because small amounts of blossom blight can support an epidemic of shoot blight and because infection of blossoms is much easier to control than infection of shoots.

A requirement governing the prediction of blossom infection in MARYBLYT is that the flowers must be open with petals intact (12). Therefore, observations on when petal fall has occurred are critical because the blossom blight infection phase of the model is disabled once the petal fall stage is reached. Severe blight can occur when straggling blooms open during petal fall (6), and this occurred again in 1991 (Fig. 3). Although predictions for blossom blight can be extended by entering the phenology stage "B" rather than "PF" in the model, this requires a judgment decision by users of the model. The chances of missing infection to straggling blooms on apple could be reduced by extending the prediction period for blossom infection in the model through, rather than to, petal fall.

The epidemic in 1991 is of special importance because very severe infection occurred without precipitation. This epidemic was nearly identical to a severe epidemic recorded in West Virginia in 1985 (17). In West Virginia and in Eau Claire, Michigan, there were several consecutive days during bloom (including petal fall in Michigan) with maximum temperatures above 26.6 C and no rain. Previously, Mills (7) found a high correlation between daily maximum temperatures greater than 26.6 C during bloom (with or without precipitation) and outbreaks of fire blight in western New York State. MARYBLYT has a requirement for rain when predicting blossom infection. Prediction of infection was possible when 0.3 mm rain was entered on days with fog and by extending bloom to account for straggling blossoms opening during petal fall (Fig. 3). Here again, whether dew or fog is important in a particular epidemic requires a judgment decision by the user of the model.

The trauma blight feature in MARYBLYT (13) was very useful in explaining the outbreak of fire blight in 1990. The term "trauma blight" was coined by Steiner (13) for sudden outbreaks of fire blight after injury to the tree by hail, wind, or other wounding agents. No blossom blight was predicted when the bloom period was extended beyond petal fall to account for possible infection to straggling blooms. It was too cold. Unlike hail, wind occurs daily and judgment is needed in deciding when wind is severe enough to influence a fire blight epidemic.

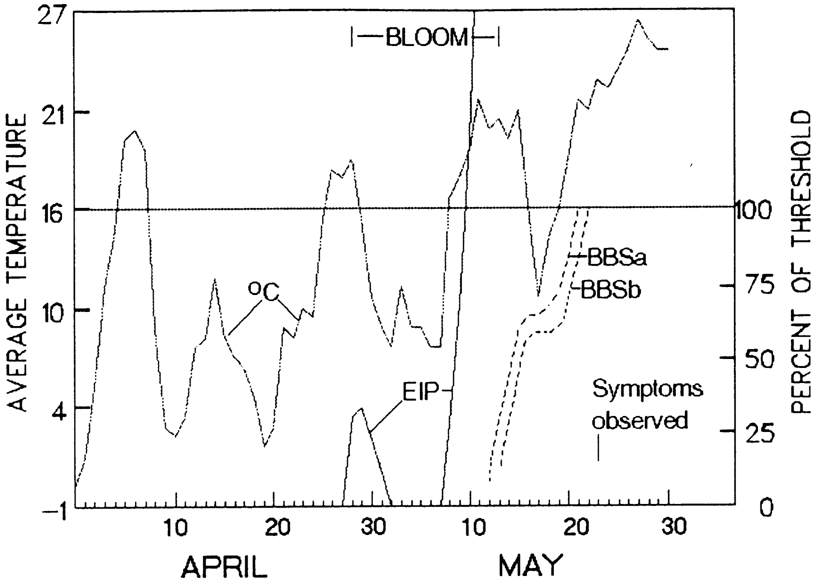

Fig. 4. Relative epiphytic inoculum potential (EIP) and anticipated symptom development for fire blight blossom infections (BBS) predicted by the MARYBLYT model based on average daily temperature, rainfall (not shown), and phenology data collected in a Jonathan apple orchard near East Lansing, Michigan, in 1991.

The MARYBLYT model for fire blight evaluates the development of several stages in the disease cycle, from overwintering canker development, buildup of epiphytic populations on blossoms, detection of weather favorable for infection, and appearance of blossom blight symptoms to the initiation and appearance of primary and secondary shoot infections. Despite its comprehensive nature, the model does not always explain for every location why fire blight does or does not develop. Despite some limitations, the model is an excellent tool for focusing the attention of growers, extension personnel, and researchers on factors known to influence the disease and on the interaction of these factors.

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