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Development of K-Maryblyt for Fire Blight Control in Apple and Pear Trees in Korea

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K-Maryblyt has been developed for the effective control of secondary fire blight infections on blossoms and the elimination of primary inoculum sources from cankers and newly emerged shoots early in the season for both apple and pear trees. This model facilitates the precise determination of the blossom infection timing and identification of primary inoculum sources, akin to *Maryblyt*, predicting flower infections and the appearance of symptoms on various plant parts, including cankers, blossoms, and shoots. Nevertheless, K-Maryblyt has undergone significant improvements: Integration of Phenology Models for both apple and pear trees, Adoption of observed or predicted hourly temperatures for Epiphytic Infection Potential (EIP) calculation, incorporation of adjusted equations resulting in reduced mean error with 10.08 degree-hours (DH) for apple and 9.28 DH for pear, introduction of a relative humidity variable for pear EIP calculation, and adaptation of modified degree-day calculation methods for expected symptoms. Since the transition to a model-based control policy in 2022, the system has disseminated 158,440 messages related to blossom control and symptom prediction to farmers and professional managers in its inaugural year. Furthermore, the system has been refined to include control messages that account for the mechanism of action of pesticides distributed to farmers in specific counties, considering flower opening conditions and weather suitability for spraying. Operating as a pivotal module within the Fire Blight Forecasting Information System (FBcastS), K-Maryblyt plays a crucial role in providing essential fire blight information to farmers, professional managers, and policymakers.

Keywords **:** apple, fire blight, disease forecast, model-based control, pear

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Despite legal prohibitions and the eradication of diseased orchard in Korea since 2015 (Myung et al., 2016; Park et al., 2016), the spread of fire blight on apple and pear trees persists. The pathogen responsible for fire blight, *Erwinia amylovora*, has the capacity to infect healthy apple and pear trees through flowers as well as newly emerged shoots, and wounds (Biggs and Turechek, 2010). The primary inoculum source is the ooze on the surface of diseased trees, which is transported by insect vectors or windy rain to the stigma of the open flowers (Johnson and Stockwell, 1998). If the pathogen population on stigma reaches a critical level due to favorable temperatures, it can travel to the host's nectary via a water film, leading to successful infection (Hattingh et al., 1986; Thomson, 1986, 2000).

The practice of controlling fire blight by spraying antibiotics, such as streptomycin, onto opened stigmas occupied by *E. amylovora*, widely adopted in the Uited States and Europe, has been considered a reasonable method to prevent flower infection. However, indiscriminate sprays on flowers have raised concerns, leading to the development of a resistant pathogen strain against antibiotics. In response to these challenges, fire blight forecasting models were developed to determine the optimal spraying time during the flowering period (Schroth et al., 1974; van der Zwet and Beer, 1991). While, fortunately, a resistant pathogen strain has not been identified in Korea, it is imperative to proactively control fire blight by developing a forecasting model tailored to the infection times.

The primary functions of a disease model is to detect and forecast infection events, aiding in the precise timing of antibiotic spraying without unnecessary control measures. Moreover, if a model can accurately predict the onset of fire blight symptoms on cankers or newly emerged shoots, it can serve as an indicator for when symptoms may appear. This facilitates the identification of optimal timing for field scouting to eliminate primary infection sources (Billing, 2000; Thomson, 2000). Given that the primary inoculum source of fire blight can potentially spread to orchards and trigger numerous infections (Thomson, 2000), eradicating them is crucial as a proactive and effective method of fire blight control.

Maryblyt was developed in Maryland, USA (Steiner, 1990a, 1990b; Steiner and Lightner, 1996; Turecheck and Biggs, 2015). It initiates its operation when the orchard reaches approximately 50% green tip (GT) emergence in apple or pear trees. Running the model requires the input of daily minimum and maximum temperatures, as well as daily precipitation data. Furthermore, it necessitates orchard-specific phenological information, including the dates of critical stages such as 50% GT, first bloom (B1), and last bloom (PF, petal fallen). Farmers are required to input this phenology based on their tree observations. During the flowering period, *Maryblyt* calculates the Epiphytic Infection Potential (EIP), representing the pathogen's density on the blossom stigma, which varies with temperature and humidity (Steiner, 1990a). Utilizing the EIP level, the program predicts blossom infection risk (BIR) and recommends antibiotic spraying. Additionally, it forecasts the dates of canker margin symptom (CMS), canker blight symptom (CBS), blossom blight symptom (BBS), shoot blight symptom (SBS), and trauma blight symptom (TBS) for a specific orchard.

The BIR is derived from four conditions, collectively known as BHWT: blossomed (B), EIP over 100 (H), more than 2.5 mm precipitation (W), and a daily average temperature higher than 15.6°C (T) (Lightner and Steiner, 1990). Temperatures exceeding the threshold of 15.6°C are known to predispose trees to fire blight infection (Billing, 1974; Smith, 1999; Steiner and Lightner, 1996). EIP serves as an index for pathogenic density and is calculated when the temperature surpasses the threshold, taking into account the age of the flowers (Zoller and Sisevich, 1979). When pathogenic density exceeds log 6 colony forming unit (cfu) on the stigma, rain or heavy dew can transport them to the nectary (Luepschen et al., 1961; Mills, 1995; Thomson et al., 1977). The BIR level is determined by the number of BHWT conditions met: 1 indicating 'Low' risk (BIR-L), 2 indicating 'Moderate' risk (BIR-M), 3 indicating 'High' risk (BIR-H), and 4 indicating 'Infection' risk (BIR-I). Since 2022, the Rural Development Administration (RDA) in Korea has recommended controlling fire blight on blossoms by spraying antibiotics when the model issues BIR-I or BIR-H warnings (Rural Development Administration, 2022, 2023).

Namkung and Yun (2023a) recommended applying streptomycin whenever EIP exceeded 100, be it BIR-I or BIR-H, to effectively control blossom infections on apple trees. The primary strategy involves maintaining the pathogenic density below 100 EIP on the stigma, constituting proactive control through continuous EIP monitoring during the flowering period, irrespective of actual infection manifestation. This approach enables the management of fire blight before visible symptoms emerge on the flowers, thanks to the ability to calculate fluctuating EIP levels based on hourly temperatures. Furthermore, both observed and predicted temperatures during the period can be leveraged to anticipate the opportune moment for control measures.

The *Maryblyt* model, operating on the Windows OS of a PC, necessitates manual input of orchard phenology and meteorological data by the farmer. Implementing fire blight control based on model recommendations requires a comprehensive understanding of *Maryblyt*'s logic. In contrast, our developed K-Maryblyt simplifies this process by providing straightforward messages, indicating the optimal timing for blossom spray or scouting of cankers and newly emerged shoots. The transition from periodic to model-based control policy for fire blight blossom infection underscores the importance of delivering field application timing with both ease and accuracy. The K-Maryblyt model facilitates this by offering an automated information system for fire blight that seamlessly collects meteorological data, predicts fire blight infection and initial symptoms, and provides accessible information on the right timing for spraying or scouting via web or mobile devices. Our primary objective is to advance K-Maryblyt as an effective tool for fire blight control, ensuring simplicity in application on the fields.

Materials and Methods

The K-Maryblyt model, utilizing the algorithm of *Maryblyt* ver. 7.1, was specifically developed for the protection of Korean apple and pear orchards against fire blight. K-Maryblyt comprises of a phenology module tailored for apples and pears, a BIR module, and a module for the appearance of BBS, CMS, CBS, and SBS symptoms (Fig. 1).

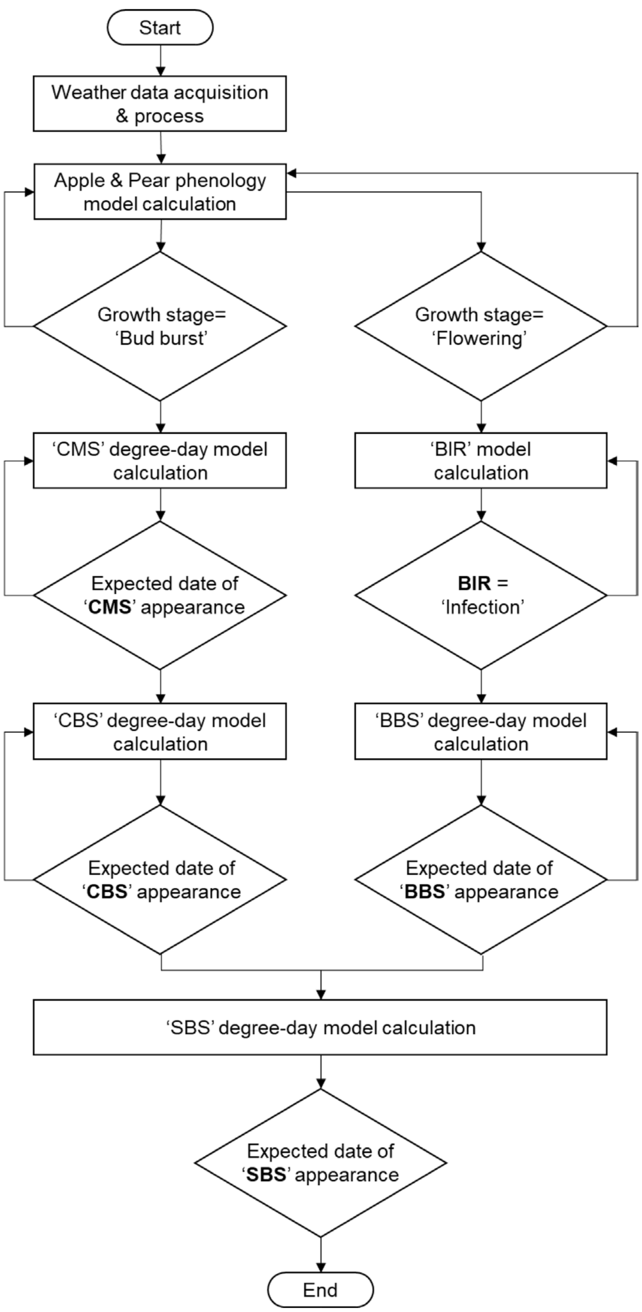

Fig. 1. Comprehensive schematic representation of K-Maryblyt, featuring a phenology module customized for apples and pears, a blossom infection risk (BIR) module, and a module for the manifestation of blossom blight symptom (BBS), canker margin symptom (CMS), canker blight symptom (CBS), and shoot blight symptom (SBS) symptoms.

Phenology module tailored for apples and pears. Rather than requiring manual input of dates such as GT, early bloom, and petal fallen for apple and pear trees in each orchard, K-Maryblyt employs estimation based on phenology models for apple (Cesaraccio et al., 2004) and pear (Han et al., 2008, 2010). In refining the parameters for these phenology models, we conducted a comparison between the model's outcomes and webcam footage from an apple orchard in Chungju and a pear orchard in Cheonan, provided by the National Institute of Horticultural and Herbal Science (https://fruit.nihhs.go.kr). Key parameters, including anti-chill days (Ca) values for apple cultivars Fuji and Hongro (Namkung and Yun, 2023b), and development rate (DVR) for pear cultivar Singo (Namkung and Yun, 2022), were adjusted accordingly.

BIR module. Similar to *Maryblyt* ver. 7.1, K-Maryblyt forecasts the BIR daily from early bloom to petal fallen day. For both apple and pear, blossom and daily average temperature are common factors among the BHWT conditions. In contrast to *Maryblyt*'s calculation of hourly temperatures using sine functions derived from daily minimum and maximum temperatures, K-Maryblyt directly employs hourly temperatures obtained from observed or forecasted Celsius (°C) temperatures.

EIP was calculated in degree-hours (DH), accumulated above the threshold temperature. The pathogenic population on the style either halted or increased slowly, depending on the age of the flowers (Gouk et al., 1996; Pusey and Smith, 2008; Thomson and Gouk, 2003). K-Maryblyt was designed to modulate the pathogenic populations based on the blossom age, set at 44.4 degree-day (DD) for apple and 66.7 DD for pear (Farkas et al., 2012). In its early iteration, K-Maryblyt underestimated EIP compared to *Maryblyt* ver. 7.1. We enhanced the model by developing adjusted versions for apple and pear. For the adjusted model, we selected the top six meteorological observed sites where the disease occurred frequently from 2015 to 2021. Additionally, we chose orchards located within 5 km of the meteorological observed sites in each host (Table 1). Out of the six selected sites, the top two were utilized for constructing the adjusted model, while the all six served for model validation.

Within the BHWT conditions, the 'W' (wet) requirement varied based on the host. In K-Maryblyt, the 'W' condition

Table 1. The top six meteorological observation sites selected based on the frequent occurrence of fire blight from 2015 to 2021 in both apple and pear orchards in Korea

Pear		Apple		Data use for model
Site	No. of orchards	Site	No. of orchards	
Anseong	29	Baegun	253	Development and Validation
Seonggeo	29	Umjeong	178	Development and Validation
Pyeongtaek	18	Seonggeo	25	Validation
Gongdo	8	Anseong	16	Validation
NMSC	6	Chungju	14	Validation
Janghowon	4	Geumwang	10	Validation

The number associated with each site represents the count of orchards affected by fire blight within a 5 km radius of the respective site. Within these six sites, the top two were utilized for developing the adjusted model, while the remaining four were employed for model validation.
NMSC, National Meteorological Satellite Center.

for apple remained the same as in *Maryblyt*. However, for pear, an additional criterion was introduced, requiring a relative humidity (RH) of 80% or more. This adjustment was made considering the dry conditions in late March or early April when pear blossoms open, ensuring a more accurate sensitivity to infection on pear trees.

Symptom module for the appearance of BBS, CMS, CBS, and SBS. Similar to *Maryblyt*, K-Maryblyt also calculates symptom development for CMS, CBS, BBS, and SBS. CMS initiation involved calculating DD from the day of 50% GT. CBS calculation commenced immediately after CMS. BBS DD calculation began after BIR-I (Infection warning). SBS DD calculation started on the day following BBS or CBS. TBS, present in *Maryblyt*, was excluded from K-Maryblyt. Both models shared the same base temperature for DD accumulation and criteria for symptoms. However, the DD calculation for predicting the expected date of fire blight symptoms differed between the two models (Table 2). Table 2 presents a comparison of the DD calculation methods used in the two models. T_{base} and T_{upper} served as the thresholds for DD calculation, with T_{base} set at 12.7°C and T_{upper} at 32.2°C (Table 2). K-Maryblyt employed the daily maximum and minimum temperatures for

Table 2. The comparison between the methods employed by K-Maryblyt and *Maryblyt* ver. 7.1 for calculating degree-days (DD) used in predicting the anticipated date of fire blight symptoms

Cases	DD functions	
	K-Maryblyt	*Maryblyt* V7.1
$T_{min} > T_{base}$	$DD = m^{\mathrm{a}} - T_{base}$	$DD = m - T_{base}$
$T_{min} \leq T_{base}$	$DD = \frac{[T_{max} + T_n^{\mathrm{b}}]}{2} - T_{base}$	$DD = \frac{1}{\pi}\left[w^{\mathrm{c}} \int_{\theta_1}^{\frac{\pi}{2}} \sin t\, dt - \int_{\theta_1}^{\frac{\pi}{2}} (T_{base} - m)\, dt\right]$
$T_{min} \leq T_{base}$ & $T_{max} \leq T_{upper}$	$DD = \frac{[T_m^{\mathrm{d}} + T_n]}{2} - T_{base}$	$DD = \frac{1}{\pi}\left[w \int_{\theta_1}^{\frac{\pi}{2}} \sin t\, dt - \int_{\theta_1}^{\frac{\pi}{2}} (T_{base} - m)\, dt\right] - \frac{1}{\pi}\left[w \int_{\theta_2}^{\frac{\pi}{2}} \sin t\, dt - \int_{\theta_2}^{\frac{\pi}{2}} (T_{upper} - m)\, dt\right]$

The calculation differs across three cases of daily temperatures. T_{min} stands for daily minimum temperature, T_{max} strands for daily maximum temperature, T_{base} stands for base temperature and T_{upper} stands for upper threshold temperature.

[a] $m = \frac{[T_{max} + T_{min}]}{2}$.

[b] $T_n = \max(T_{min}, T_{base})$.

[c] $w = \frac{[T_{max} - T_{min}]}{2}$.

[d] $T_m = \min(T_{max}, T_{upper})$.

DD accumulation (Anandhi, 2016). Any daily temperatures exceeding or falling below the thresholds were adjusted to match them. In contrast, *Maryblyt* utilized the method introduced by Baskerville and Emin (1969), later expanded by Arnold (1960). Symptom appearance dates could be predicted based on DD accumulation in both models. Specifically, CMS was projected to appear when DD reached 110 from the date of 50% GT, while CBS was expected to manifest after accumulating 57 DD from the predicted CMS date.

Comparison symptom prediction between *Maryblyt* and K-Maryblyt in apple and pear orchards. First, to compare the symptom predictions of the two models, we selected the most severely affected sites. Meteorological data for DD calculation were obtained from the RDA and the Korea Meteorological Administration (KMA) between 2015 and 2021. From a total of 35 meteorological observation sites, we identified eight sites where the occurrence of diseased orchards within a 5 km radius was higher than the average over the last 7 years. The names of the eight sites were Anseong, Seonggeo, Pyeongtaek, Gongdo, Baegun, Umjeong, Bogae, and Ipjang. Expcet the last two on the list, the remaining six sites were listed in Table 1.

Using both models, we computed the anticipated dates of CBS occurrences in both apple and pear orchards from 2015 to 2023 across the eight selected sites. Among the reports of suspected fire blight symptoms from apple and pear farmers to the RDA, 552 cases were diagnosed in apples and 225 cases in pears. The CBS prediction days generated by both models for apple and pear trees were compared with the dates reported by the farmers as the initial occurrence.

Results

Revision of K-Maryblyt. K-Maryblyt underwent several key revisions compared to *Maryblyt*: (1) Inclusion of phenology models: K-Maryblyt integrates phenology models for both apple and pear trees, eliminating the need for manual input of blossom dates; (2) Temperature input for EIP: Unlike *Maryblyt*, which estimates hourly temperatures from daily minimum and maximum temperatures, K-Maryblyt directly utilizes observed or predicted hourly temperatures for EIP calculations; (3) Application of adjusted equations for EIP: K-Maryblyt incorporates adjusted equations, resulting in a decrease in the mean error for apple to 10.08 DH and for pear to 9.28 DH. Additionally, the coefficients of determination for apple and pear improved to 0.001 and 0.0293, respectively (Table 3); (4) Inclusion of relative humidity for pears: A variable for RH was introduced in EIP calculations for pears. If precipitation exceeds 2.5 mm in a day, the wet condition is considered for that day and following day. If there is precipitation is less than 2.5 mm or less, or if the RH is 80% or more for pears, it is also regarded as a wet condition; (5) Adjusted DD calculation methods for expected symptoms: K-Maryblyt adopted modified DD calculation methods for expected symptoms, aligning with prevalent practices in insect modeling in Korea.

EIP adjusted model. EIPs from 2015 to 2021, calculated by both *Maryblyt* and K-Maryblyt in each host, were employed for the regression analysis of the two models. The resulting regression models for each host were formulated as quadratic equations (Fig. 2). Based on data from 431 diseased apple orchards at Baegun and Umjeong sites, the adjusted EIP model for apples was $y = 0.0005*x^2 = 1.0302*x + 2.6229$. This indicates that the EIP values obtained from *Maryblyt* and K-Maryblyt for apples were closely aligned. In contrast, for 58 diseased pear orchards at Ansung and Seonggeo sites, the adjusted EIP model for pears was $y = –0.0031*x^2 = 1.6273*x + 1.7298$. As the EIP values increased in K-Maryblyt, they tended to underestimate those of *Maryblyt* for pears. Hence, adjusting EIP is crucial for accurate pear EIP calculations. The validation of these regression models was conducted using EIP data from the six listed sites.

Table 3. Enhancement of ME and RMSE in calculating EIP on apple and pear trees through the AAM derived from field data regressions

Host	EIP	ME (DH)	RMSE (DH)	R^2
Apple	EIP before AAM	–10.3	25.2	0.9299
	EIP after AAM	0.22	21.2	0.9309
Pear	EIP before AAM	–9.8	19.6	0.9042
	EIP after AAM	0.52	13.1	0.9335

ME, mean error; RMSE, root mean squared error; EIP, Epiphytic Infection Potential; AAM, application of adjusted models; DH, degree-hours.

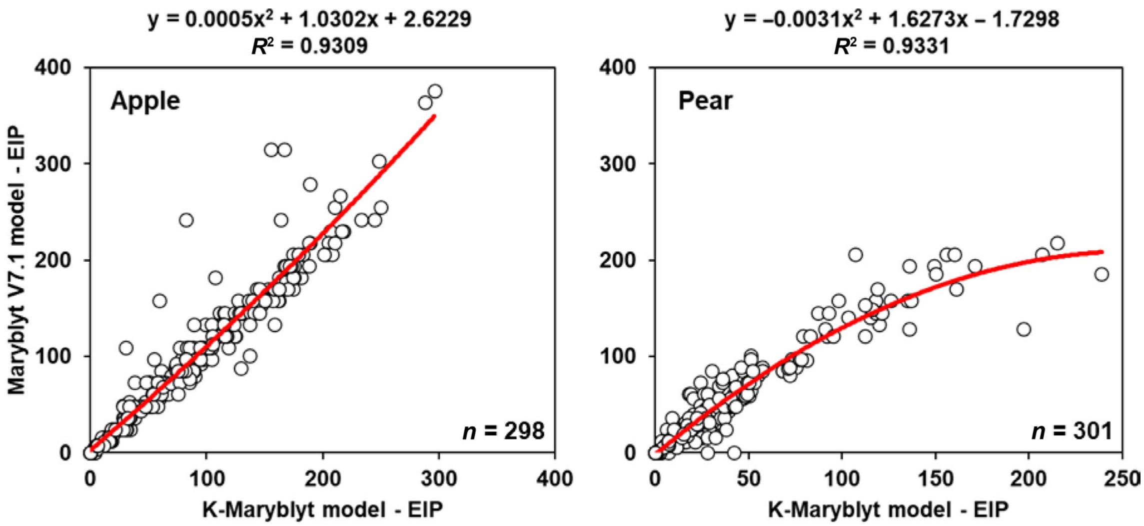

Fig. 2. Two regression analyses for the adjusted Epiphytic Infection Potential (EIP) on apple and pear trees, utilizing orchard data gathered from the most severely affected areas in Korea between 2015 and 2021. EIP calculations were performed using both *Maryblyt* and K-Maryblyt for each host.

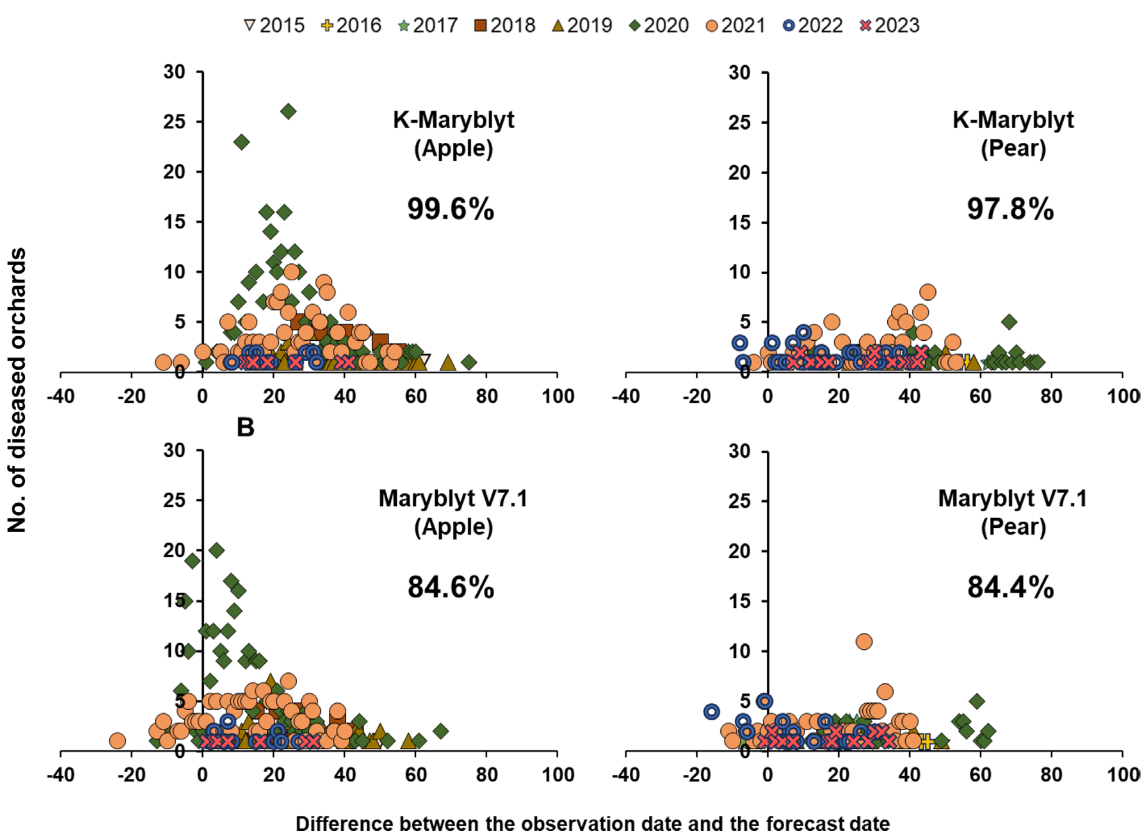

Fig. 3. Evaluation of canker blight symptom (CBS) appearance by K-Maryblyt and *Maryblyt* involved comparing the calculated CBS days in apple and pear tree with the observed dates of suspicious fire blight symptom dates reported by farmers. The percentages in each panels indicated instances where the model forecasted CBS earlier than the actual symptom appearance. From the selected 8 sites, which were the most severe outbreaks, 552 cases were diagnosed in apples and 225 cases in pears from 2015 to 2023.

Comparison symptom prediction of the two models. The CBS prediction days for apple and pear trees generated by both models were juxtaposed with the symptom onset dates reported by farmers (Fig. 3). The x-axis represents the discrepancy in days between the model-predicted and farmer-reported symptom dates. A negative value indicates that actual symptoms appeared earlier than the model's CBS prediction. With the exception of 2020, most discrepancies fell within the range of –10 to +40 days, signifying that fire blight symptoms manifested either up to 10 days before or up to 40 days after the model's CBS forecast.

Out of the 552 fire blight symptom cases reported on apple trees from 2015 to 2023, *Maryblyt*'s predictions preceded the actual observations in 84.6% of cases, whereas K-Maryblyt achieved an anticipatory prediction rate of 99.6%. In addition, out of 225 fire blight symptom cases on pear trees, *Maryblyt*'s predictions preceded the actual observations in 84.4% of cases, whereas K-Maryblyt achieved an anticipatory prediction rate of 97.8%.

Discussion

Since 2015, when fire blight occurrences were first recorded, we have been running *Maryblyt* on both apple trees (Namkung and Yun, 2023a) and pear trees (Namkung and Yun, 2022) to manage blossom infection during the flowering periods. The BIR-Infection days were at most two or three days throughout the season, and there were no BIR-I days in pear trees in 2018 and 2021. This indicates that model-based antibiotic spray may not raise concerns about the emergence of resistant pathogens. However, Korean farmers typically prefer to spray at least twice during flowering, without any no-spray exceptions. Namkung and Yun (2023a) proposed a viable control method utilizing the K-Maryblyt model, ensuring clarity in the field with 2 or 3 times of model-based sprays. Ahn and Yun (2021) further reported that in the most severely affected fire blight area in Chungbuk apple orchards, model-based control would be a reasonable approach.

Based on the findings of Pusey (2000), the pathogenic population exhibited fluctuations between log 3.0 and log 6.0 cfu on the styles at RH ranging from 40% to 100% during the flowering infection. However, the population remained relatively stable within the hypanthium until it fell below 80% RH. Beyond this threshold, it rapidly increased, reaching log 6.0 cfu, a concentration sufficient for infection, especially at 95% RH. This underscores that high RH is another conducive condition for the proliferation of *E. amylovora*. Consequently, we adjusted the wet condition in K-Maryblyt for calculating EIP on pears. This adaptation aims to safeguard against pear blossom infection under conditions of high RH in the field.

Canker blight symptoms persistently occur in areas where fire blight is prevalent, and BBSs can be readily identified where numerous BBS instances exist (Steiner, 1990b). Newly emerged shoots exhibiting fire blight symptoms are typically observed within seven to ten days following the onset of CBS or BBS. Following the adjustment of the DD method in K-Maryblyt, we achieved an accuracy improvement of 10% or more in both apple and pear trees. The timing of appearance of BBS or CBS is contingent on weather conditions from GT to the first blossom day. In our apple fire blight cases, symptoms such as blossom, canker, and shoot varied. Farmers should vigilantly observe various symptoms on flowers, shoots, and cankers in an orchard when CBS, BBS, and SBS are predicted.

Due to the aging demographic in the Korean fruit industry, the adoption of information on smart devices has proven to be challenging. With the exception of areas experiencing a severe occurrence of fire blight, many fruit farmers remain unaware of antibiotic control methods for apple or pear flowers. The RDA has recognized the need for nationwide fire blight forecasting and control. Consequently, the RDA advocates for the development and utilization of K-Maryblyt from the early stages of disease occurrence. The K-Maryblyt developed in this study serves as one module within the Fire Blight Forecasting Information System (FBcastS). FBcastS is designed to operate automatically on web or mobile devices, encompassing the collection of meteorological data, estimation of apple and pear phenology, prediction of appearance dates for BIR, BBS, CMS, CBS, and the dissemination of fire blight information via web and smartphones. Since the transition to a model-based control policy in 2022, the system has sent 158,440 messages regarding blossom control and symptom prediction to farmers and professional managers (Ahn et al., 2022). Furthermore, the system has been enhanced to include control messages that consider the mechanism of action of pesticides distributed to farmers in specific counties, along with the conditions of flower opening and weather suitable for spraying.

When we initially applied the early version of K-Maryblyt to orchards, challenges arose concerning the prediction of blossom opening, particularly in apple orchards. For instance, there were instances where K-Maryblyt issued a warning for flower infection in a specific area, but the flowers had not yet opened. This discrepancy led to farmers distrusting the model, which was designed to automate phenology. Accurate prediction of blossom opening, especially from B1 (first flower) to BB (80% of the flowers opened), is crucial for effective fire blight blossom control, and the disease model should precisely forecast flower infection during this critical period (Namkung and Yun, 2023b). To address this issue, we incorporated webcam footage from apple and pear orchards, using this information to refine major parameters in the apple and pear phenology models. Currently, K-Maryblyt is deemed sufficient for use in severely affected areas. However, future improvements should involve acquiring more webcam information, particularly from regions not currently covered, such as southern areas for pears and border areas for apples.

The proactive methods for fire blight control, implemented before typical symptoms manifest on the hosts, involve identifying the primary inoculum source on overwintered cankers and eliminating them. Another approach is to effectively manage blossom infection by determining the infection time. Furthermore, predicting the timing of typical symptoms on flowers, cankers, and newly emerged shoots allows for thorough scouting in orchards. Since K-Maryblyt provides warnings not only for BIR-Infection but also for BIR-High, we can monitor EIP levels, ensuring they remain below 100, using forecasted temperatures. If the decision is made to control blossom infection solely based on BIR-I, predicting precipitation during the flowering season becomes more challenging than forecasting temperatures. By focusing solely on forecasted temperatures during the season for blossom blight control, predictions become more manageable before the onset of infection.

Now, the Fire Blight Forecasting Information System (FBcastS) is operational, collecting observed and 48-h forecasted meteorological data from 1,500 monitoring sites with a 3-hour interval. The development of K-Maryblyt in this study is integrated into the system, providing crucial fire blight information to farmers, professional managers, and policymakers. In 2023, the Korean government provided pesticides for fire blight, comprising 52.1% chemical and antibiotic pesticides. This represents a decrease from 66.7% in 2021 and 55.3% in 2022. This decline may be attributed to lingering concerns among some Korean farmer regarding potential flower damage caused by streptomycin (Ham et al., 2023). This underscores the need for education on fire blight control using the K-Maryblyt model. K-Maryblyt currently does not include the prediction of TBS appearance, accounting for various traumas such as frost, hail, and wounds from pruning. Continuous improvement of K-Maryblyt is essential to address challenges that may arise.

Conflicts of Interest

No potential conflict of interest relevant to this article was reported.

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