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RESEARCH ARTICLE

## The Maryblyt Prediction System for Identifying Fire Blight Infection (*Erwinia Amylovora*) in Fruit-Bearing Trees – Seeds in the Tirana Region

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### ABSTRACT

Fire blight caused by the bacterium *Erwinia amylovora* is the most significant, serious, and complex disease affecting pome fruit trees. *E. amylovora* is considered one of the most dangerous diseases of pome fruit trees worldwide. Currently, legal and quarantine measures are in place to prevent the introduction and spread of infected propagating and planting material by *E. amylovora*. This research aims at the integrated management of fire blight through a combination of chemical and mechanical measures applied at critical stages of host plant infection, utilizing the Maryblyt forecasting program. The application of the Maryblyt system for determining infection risk periods is calculated based on degree days (DD) above 12.7°C, which is considered the lowest threshold for pathogen development. Examination of overwintering canker status revealed that the active inoculum was activated at the margins of softened tissues of these cankers when 59.2°C (DD) above 12.7°C had accumulated from the green tip stage. Blossom symptoms appeared when 98.3°C (DD) above 12.7°C had accumulated from the green tip stage. Shoot symptoms appeared when 158.8°C (DD) above 12.7°C had accumulated from the green tip stage. These are the potential infection periods, which enable timely treatment planning and help avoid unnecessary treatments.

**Keywords:** *Erwinia amylovora*, active inoculum, Maryblyt system, symptoms.

### INTRODUCTION

*Erwinia amylovora* is one of the most dangerous bacterial diseases, affecting pear, apple, and quince, and is rarely found in other pome fruit crops. It was the first bacterium described as the causal agent of a plant disease (Burrill, 1883). *E. amylovora* is the causal agent of fire blight, a disease that affects most species of the subfamily *Maloideae* of the family *Rosaceae* (*Spiraeoideae*) (EPPO, 2022). Although discovered in the 1800s, fire blight continues to cause tremendous economic losses for the apple and pear industries centuries later (Zeng *et al.*, 2023). In many areas where apples are grown, fire blight (*E. amylovora*) is a sporadic but potentially devastating disease (Rougerie-Durocher

*et al.*, 2020; Azeem *et al.*, 2020). Caused by *E. amylovora*, it infects flowers, shoots, and fruits, creating canker lesions on the bark of branches and trunks, and leading to yield reduction and tree death (Van Der Zwet and Keil, 1979). A devastating outcome of fire blight in apple trees is the infection of rootstock, which leads to canker development (Aćimović, 2023). Fire blight cankers are infected zones of dead bark on perennial branches, trunks, or rootstocks that develop after the *E. amylovora* pathogen invades wood. The pathogen overwinters in cankers; ooze exudes from cankers and can be carried by insects, such as flies, to flowers (Holland, 2021; Haq *et al.*, 2021; Atiq *et al.*, 2023). Most primary infections

occur on the blossoms as the bacteria invade the plant through natural openings called nectaries (Sharma, 2024). After settling on the floral parts, the bacterium multiplies and penetrates the interior of the flower (Susuri *et al.*, 2012). It then develops within floral tissues before invading the shoots and branches. Infection can occur in several phenological phases, but it mostly starts with an infection of flowers. Once the bacteria invade and kill the cambial tissue of the branch, all flowers, leaves, and fruit above the girdled area die. Host plants are infected systemically, causing tracheobacteriosis, a sudden necrosis of foliage, flowers, and fruits (Ágoston *et al.*, 2020). Fire blight outbreaks may be associated with many factors, including the presence of large numbers of susceptible hosts, favorable climatic conditions, and efficient dissemination (Sun, 2023; Ali *et al.*, 2024). Environmental conditions that promote disease development include humid or rainy weather with temperatures ranging from a low of 12.7°C at night to a high of 23.9-29.4°C during the day (Pinnell-Alison, 2025). This disease has caused significant economic losses in many European and Mediterranean countries, where commercial cultivars of apple and pear are often susceptible (Ruz, 2008). Fire blight is a significant threat to the EPPO region, and *E. amylovora* is one of the most important diseases listed in the A2 list of the European and Mediterranean Plant Protection Organization (EPPO). Although quarantine measures have reduced infection levels annually (Vrancken, 2013), management remains challenging. Many efforts have been to stop the occurrence and impacts of fire blight, but in many countries, only preventive measures are used due to restrictions on antibiotics and copper-based compounds (Mendes, 2024). Control strategies include infection prediction models, chemical and biological treatments, the development of resistant cultivars, and balanced fertilization. Forecasting models help identify potential infection periods and allow for timely treatment planning while avoiding unnecessary treatments. One such model, Maryblyt, developed by Steiner & Lightner (1992; 1996) has been widely used by agronomists of the Atlantic region. It predicts infection events by identifying periods when weather conditions and tree phenology are suitable for infection, allowing growers to apply antibiotics at optimal times (Ayer *et al.*, 2021). Pedroncelli (2023) suggests that the use of different strategies might possibly enhance the chance of

reaching complete fire blight control. Finally, new research, methods, and legislation must be issued to control this dangerous phytopathogen and its global spread (Fendrihan *et al.*, 2019), and the introduction of new biopesticides must be accompanied by standards and regulations for their safe use.

## MATERIALS AND METHODS

### Monitoring Disease Infection Using the Maryblyt Program:

Monitoring the development of infection in the Gala apple cultivar is based on climatic conditions (minimum and maximum daily temperatures in °C, precipitation in mm, air humidity in %, and atmospheric events such as fog, heavy dew, and storms), as well as the phenological growth phases of apples, combined with the critical threshold for pathogen development. The determination of infection risk periods is calculated based on degree-days (DD) above a temperature of 12.7°C, which is considered the lowest threshold for pathogen development (Steiner & Lightner, 1996). Daily data collection begins from the appearance of the green tip stage. This data is then used to signal when symptoms are likely to appear in the orchard. The Maryblyt program operates in °F. By calculating the recorded temperatures and accumulating 33.9°C (DD) above 12.7°C from the green tip stage, the active inoculum may appear. From the appearance of active inoculum until the accumulation of an active temperature sum of 39.4°C (DD) above 12.7°C, i.e., 93.3°C (DD) above 12.7°C from the green tip stage, flower blight occurs. By continuing to monitor and calculate active temperatures above 12.7°C, when 148.9°C (DD) above 12.7°C is accumulated from the green tip stage, shoot infection may occur (Steiner & Lightner, 1996). Based on observations of infected trees, recorded weather conditions, and the phenological growth stages of apples, the appearance of primary inoculum on overwintering cankers, flower blight, and shoot blight has been identified.

For temperature conversions between °C and °F, the following formulas are used:

- $^{\circ}\text{F} = (^{\circ}\text{C} \times 9/5) + 32$
- $^{\circ}\text{C} = (^{\circ}\text{F} - 32) \times 5/9$

**Location of the Experiment:** The study was conducted in 2024 in a 10-year-old apple orchard with the “Gala” cultivar, an early and sensitive variety, where a natural fire blight infection was present. This orchard is located in the village of Laknas, covering an area of 1 hectare on the outskirts of Tirana.

**Monitoring the Phenological Phases of Apples:** The

phenological development of apple trees was monitored through observations every 7-10 days, focusing primarily on the following phenological stages: bud break, green tip, pink bud, bloom, petal fall, and post-bloom (fruit growth).








**Monitoring of Weather and Climatic Conditions:** Daily monitoring of maximum and minimum temperatures, relative air humidity, daily precipitation, and atmospheric events was conducted. By recording daily maximum and minimum temperatures, the degree-day (DD) sum above 12.7°C was accumulated to determine the most critical infection risk periods.

**RESULTS AND DISCUSSION**

The apple orchard with the “Gala” cultivar in this study had a natural fire blight infection. Infected trees showed clear disease symptoms, including blackened shoots, overwintering cankers on the trunks, and blackened areas on some branches. Based on the data, the most critical durations in the development of the disease during this sensitive growth period were the appearance of the active inoculum, symptoms on flowers, and signs on shoots. The trees in the study broke dormancy and resumed the vegetative phase by showing the silver tip (bud swelling) on March 16, 2024, with a daily maximum temperature of 19°C, a minimum daily temperature of 6.7°C, and an average daily temperature of 12.9°C, with relative air humidity of 70.8%. The green tip stage was recorded on March 26, with a maximum temperature of 18°C, a minimum temperature of 7.1°C, an average temperature of 13.9°C, and relative air humidity of 80.3%. Observations of the overwintering cankers showed that the active inoculum was activated at the boundaries of the soft tissue of these cankers when 59.2°C (DD) above 12.7°C was accumulated from the green tip phase, with relative humidity of 80.3%, accompanied by fog. The activation of the cankers consists of bacterial cell multiplication in healthy bark tissue around the cankered areas. As multiplication continues, the bacteria invade

new healthy bark tissue, causing additional damage to the tree. The inoculum produced by overwintering cankers may be either invisible or visible as flowing droplets of exudate on the bark surface. In spring, bacteria can be carried by wind, rain, bees, and other insects from the overwintering cankers to flowers or young shoots, initiating infection. On April 2, the trees were in the pink bud stage, and four days later, blooming began. The pink bud stage occurred with a maximum temperature of 20°C, a minimum temperature of 13.3°C, and an average temperature of 16.4°C. This stage occurred with relative air humidity of 71.6%. Blooming began on April 6 and ended on April 10 when 44 DD above 4°C were accumulated. Apple flowers remain open for about 44 DD above 4°C (Steiner & Zwet, 1996). Approximately 65–70% of floral buds open during full bloom. The onset of blooming was accompanied by a maximum temperature of 23.6°C, a minimum daily temperature of 10.7°C, and an average daily temperature of 15.9°C. Symptoms on flowers appeared on April 4 when 98.3°C (DD) above 12.7°C were accumulated from the green tip stage. At that time, the trees were in the pink bud stage. The appearance of symptoms on the flowers was accompanied by a storm and relative humidity of 66.9% (Tab. 1, 2, and Fig.1). Symptoms on shoots appeared on April 9, when 158.8°C (DD) above 12.7°C were accumulated from the green tip stage. One day before the symptoms appeared on the shoots, there was fog. At this time, the apple trees were at the end of the bloom stage. This stage occurred with a maximum temperature of 26.2°C, a minimum temperature of 13.1°C, and an average temperature of 19°C, with relative humidity of 69.8%. The petal fall phase was accompanied by a maximum daily temperature of 24°C, a minimum temperature of 16.3°C, an average temperature of 18.9°C, and relative humidity of 73.7%, along with dew and fog.

Table 1. Phenological development of apples for the year 2024

| Apple cultivar  | Bud swelling  | Green tip   | Pink  | Bloom  | Petal fall  | Fruit set   |
|---|---|---|---|--|---|---|
|  |  |  |  |  |  |  |
| Gala  | 16.03.2024  | 26.03.2024  | 02.04.2024  | 06.04.2024   | 16.04.2024  | 18.04.2024  |

Note: Early and sensitive cultivar

Source: Prepared on the basis of research data by Boechel (2022) and apples gala cultivar based on the link <https://www.oberhoferb.com/en/gala.php>

Table 2. Climatic data for the period March-April 2024. The duration of the open flower around 44 DD, is calculated from the average daily temperature – 4°C. According to the data received from the metrological station in Tirana.

| Month Date | Temperature °C |      |      | Air Humidity | Rainfall | Atmospheric event | Degree greater than 12,7°C |             | Notes                                |
|------------|----------------|------|------|--------------|----------|-------------------|----------------------------|-------------|--------------------------------------|
|            | Max            | Min  | Avg  | %            | mm       |                   | Daily                      | Progressive |                                      |
| March 2024 |                |      |      |              |          |                   |                            |             |                                      |
| 01         | 18.6           | 9.4  | 13.9 | 73.4         | 4        |                   | 5.9                        |             |                                      |
| 02         | 17.8           | 12.2 | 12.2 | 79.9         | 0.3      |                   | 5.1                        |             |                                      |
| 03         | 19             | 12.4 | 12.4 | 77.1         | 1.7      |                   | 6.3                        |             |                                      |
| 04         | 19             | 12.2 | 12.2 | 84.5         | 11.9     |                   | 6.3                        |             |                                      |
| 05         | 13.2           | 10.1 | 10.1 | 86.2         | 6.2      |                   | 0.5                        |             |                                      |
| 06         | 17             | 11.7 | 11.7 | 79.4         | 11       |                   | 4.3                        |             |                                      |
| 07         | 15             | 9.3  | 9.3  | 74.9         | 10.5     |                   | 2.3                        |             |                                      |
| 08         | 17.2           | 3.7  | 9.8  | 73.5         | 0        |                   | 4.5                        |             |                                      |
| 09         | 16             | 7    | 11.2 | 76.7         | 7.2      |                   | 3.3                        |             |                                      |
| 10         | 21.4           | 10   | 14.9 | 66.4         | 0        |                   | 8.7                        |             |                                      |
| 11         | 20.4           | 10.2 | 13.2 | 79.1         | 11.7     | Storm             | 7.7                        |             |                                      |
| 12         | 15.6           | 9.3  | 11.3 | 81           | 19.7     | Storm             | 2.9                        |             |                                      |
| 13         | 17             | 6.2  | 11.3 | 78.8         | 1.3      |                   | 4.3                        |             |                                      |
| 14         | 17.4           | 5.3  | 10.9 | 78.2         | 0        |                   | 4.7                        |             |                                      |
| 15         | 19.6           | 6.7  | 12.1 | 73.6         | 0        |                   | 6.9                        |             |                                      |
| 16         | 19             | 6.7  | 12.9 | 70.8         | 0        |                   | 6.3                        |             | Silver Tip                           |
| 17         | 20.4           | 8.7  | 13.6 | 75.7         | 2.2      |                   | 7.7                        |             |                                      |
| 18         | 21             | 8.5  | 13.9 | 77.8         | 0        |                   | 8.3                        |             |                                      |
| 19         | 17.2           | 5.6  | 12.3 | 78.3         | 19.3     |                   | 4.5                        |             |                                      |
| 20         | 20.2           | 1.9  | 11   | 53.1         | 0        |                   | 7.5                        |             |                                      |
| 21         | 19             | 6.5  | 11.4 | 74.4         | 0        |                   | 6.3                        |             |                                      |
| 22         | 20             | 6.2  | 12.3 | 75.4         | 0.8      |                   | 7.3                        |             |                                      |
| 23         | 20             | 5.5  | 12.4 | 75.7         | 0.5      |                   | 7.3                        |             |                                      |
| 24         | 19.2           | 8.9  | 14.3 | 70.8         | 2.7      | Fog & Storm       | 6.5                        |             |                                      |
| 25         | 18.2           | 7.1  | 12.3 | 74.3         | 10.6     |                   | 5.5                        |             |                                      |
| 26         | 18             | 7.1  | 13.9 | 80.3         | 2.4      | Fog               | 5.3                        | 5.3         | Green Tip                            |
| 27         | 26.4           | 13.7 | 19.2 | 70.8         | 1.2      |                   | 13.7                       | 19          |                                      |
| 28         | 19.7           | 9.9  | 14.6 | 72.1         | 13.1     |                   | 7                          | 26          |                                      |
| 29         | 22.4           | 10.3 | 16   | 69.1         | 0        |                   | 9.7                        | 35.7        |                                      |
| 30         | 22.7           | 11.6 | 17.2 | 72.9         | 0        | Storm             | 10                         | 45.7        |                                      |
| 31         | 26.2           | 12.9 | 19   | 89.5         | 0        |                   | 13.5                       | 59.2        | Active Inoculum                      |
| April 2024 |                |      |      |              |          |                   |                            |             |                                      |
| 01         | 27.5           | 13.2 | 21.2 | 54           | 0        | Storm             | 14.8                       | 74          |                                      |
| 02         | 20             | 13.3 | 16.4 | 71.6         | 0.3      |                   | 7.3                        | 81.3        | Pink                                 |
| 03         | 21             | 8.9  | 14.6 | 73.9         | 0        | Fog               | 8.3                        | 89.6        |                                      |
| 04         | 21.4           | 10   | 14.9 | 66.9         | 0        | Storm             | 8.7                        | 98.3        | Symptoms in flowers                  |
| 05         | 23.4           | 11   | 15.5 | 76.7         | 0        |                   | 10.7                       | 109         |                                      |
| 06         | 23.6           | 10.7 | 15.9 | 83.6         | 0        |                   | 10.9                       | 119.9       | Bloom                                |
| 07         | 24             | 11.7 | 16.8 | 84.1         | 0        |                   | 11.3                       | 131.2       |                                      |
| 08         | 26.8           | 9.9  | 18.3 | 70.4         | 0        | Fog               | 14.1                       | 145.3       |                                      |
| 09         | 26.2           | 13.1 | 19   | 69.8         | 0        |                   | 13.5                       | 158.8       | Symptoms in the shoot (End of bloom) |
| 10         | 26             | 13.6 | 18.2 | 69.1         | 0        |                   | 13.3                       | 172.1       |                                      |
| 11         | 27.6           | 14   | 19.8 | 73.3         | 0.1      | Storm             | 14.9                       | 187         |                                      |
| 12         | 29.2           | 11.3 | 20.7 | 68.8         | 0        |                   | 16.5                       | 203.5       |                                      |
| 13         | 28.4           | 12.8 | 21.4 | 71.5         | 0        |                   | 15.7                       | 219.2       |                                      |
| 14         | 29             | 15.9 | 18.9 | 70.6         | 0        |                   | 16.3                       | 235.5       |                                      |
| 15         | 28.8           | 14.4 | 21.4 | 65.2         | 0        |                   | 16.1                       | 251.6       |                                      |
| 16         | 24             | 16.3 | 18.9 | 73.7         | 8.2      | Storm, Fog        | 11.3                       | 262.9       | Petal Fall                           |
| 17         | 16.8           | 12.1 | 15.1 | 87.2         | 36.7     |                   | 4.1                        | 267         |                                      |

|    |      |      |      |      |      |       |      |       |           |
|----|------|------|------|------|------|-------|------|-------|-----------|
| 18 | 18.8 | 9.8  | 13.1 | 71.2 | 3.7  |       | 6.1  | 273.1 | Fruit Set |
| 19 | 15.2 | 7.2  | 11.6 | 72.5 | 5.5  |       | 2.5  | 275.6 |           |
| 20 | 18.2 | 6.3  | 12.6 | 69.1 | 1.1  |       | 5.5  | 281.1 |           |
| 21 | 13.4 | 9.2  | 11.1 | 87.4 | 23.1 |       | 0.7  | 281.8 |           |
| 22 | 20.6 | 6.8  | 13.8 | 76.9 | 0    | Storm | 7.9  | 289.7 |           |
| 23 | 16.3 | 11.8 | 14   | 97.9 | 30.5 | Storm | 3.6  | 293.3 |           |
| 24 | 19   | 10.3 | 14.2 | 72.4 | 1.5  |       | 6.3  | 299.6 |           |
| 25 | 17.6 | 9.7  | 12.9 | 78.5 | 5.2  | Storm | 4.9  | 304.5 |           |
| 26 | 19.8 | 8.4  | 13.9 | 76   | 0.2  |       | 7.1  | 311.6 |           |
| 27 | 22.8 | 11.5 | 16.5 | 76   | 0.2  | Storm | 10.1 | 321.7 |           |
| 28 | 26.4 | 11.3 | 18.5 | 70.7 | 0    |       | 13.7 | 335.4 |           |
| 29 | 28.2 | 10.3 | 19.7 | 66.7 | 0    |       | 15.5 | 350.9 |           |
| 30 | 28.2 | 11.3 | 20.4 | 62.2 | 0    |       | 15.5 | 366.4 |           |

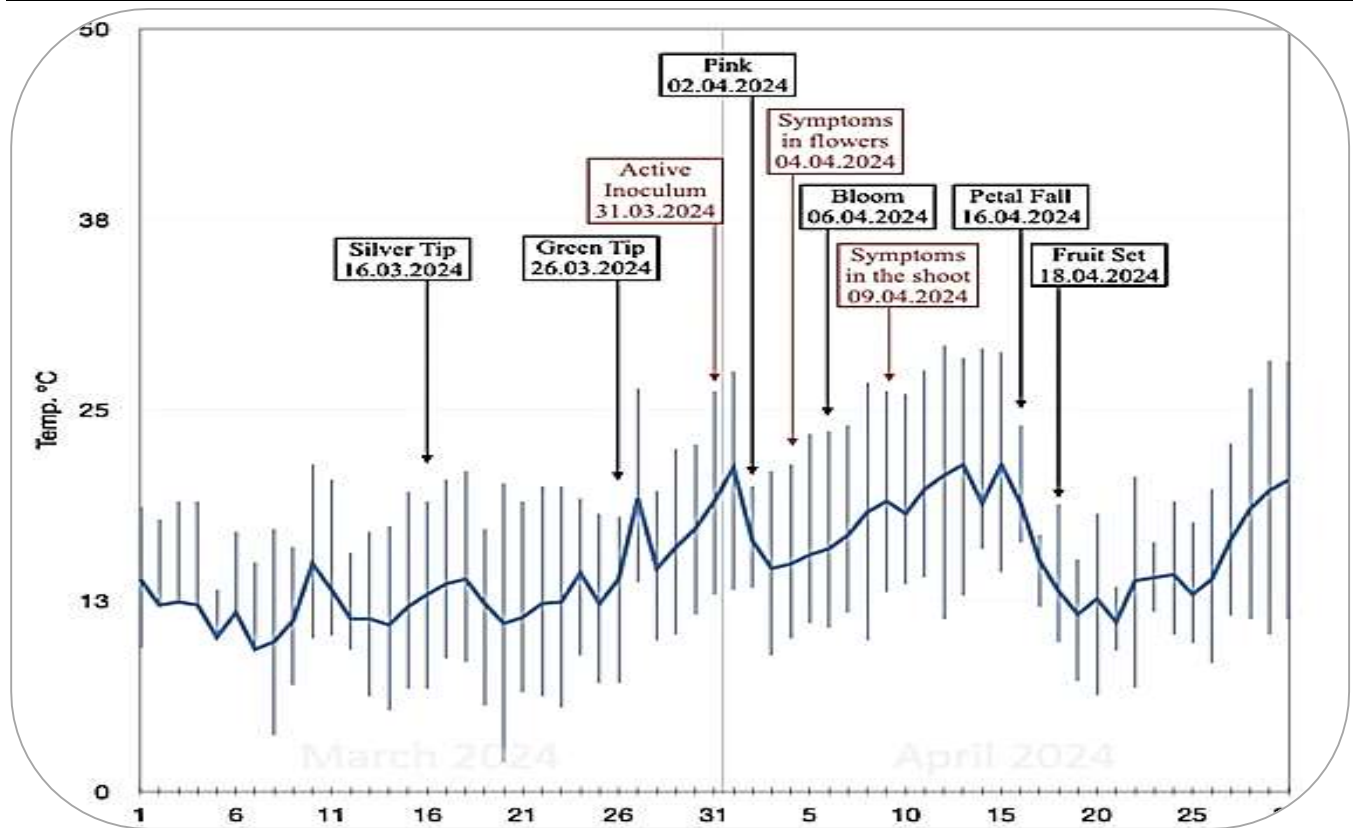


Figure 1. With strips of paint in the background, periods with atmospheric events such as rain or storms are shown. The graphic shows when the important events occurred in the plant, such as the phenological phases and the manifestations of the disease (according to the data in the Tables 1 and 2).

According to the literature, the greatest contribution to inoculum formation comes from cankers located on branches with a diameter smaller than 38 mm (1.5 inches), especially around cuts made the previous year to remove scorched branches.

First, the primary infection of fire blight occurs in spring when bacteria infect the flowers or shoots of the host plant. The bacteria may originate from cankers from the previous year, which are activated early in spring with the onset of new vegetation. They can also be “resident bacteria” (permanent) found inside or on the surface of

plant tissues. The activation of the active inoculum occurred at a cumulative sum of active temperatures (>12.7°C) of 59.2°C from the green tip stage, during the green tip phase on March 31, 2024.

Second, the wilting of buds and flowers is the first symptom of fire blight infection. This occurs early in spring but may also appear during a second bloom in autumn. The infection can spread through the base of the cluster and then affect the flowers of the same cluster, which develop the same symptoms.

The symptoms on flowers occurred at a cumulative sum

of active temperatures (>12.7°C) of 98.3°C from the green tip stage, during the pink bud phase on April 4, 2024. After the flowers, the young shoots or tender shoots in the ongoing vegetative phase are highly susceptible to infection.

Third, the symptoms of shoot infection are similar to those of flowers or leaves, but the infection progresses much more quickly under specific weather conditions. Within a few days, the infection in the shoots can advance 15–30 cm or more. In England, this movement is reported to be 25–50 mm per day (Lelliot, 1979). The symptoms on the shoots appeared after accumulating 158.8°C of active temperatures (>12.7°C) from the green tip stage, during the bloom phase on April 9, 2024.

These infection periods allow for timely treatment planning and help avoid unnecessary treatments. The results from applying the Maryblyt prediction program in the integrated management of fire blight caused by *E. amylovora* are consistent with global literature findings by authors such as Steiner *et al.* According to Steiner (2000), bacterial multiplication and the resumption of infectious activity in areas with canker lesions begin in early spring at around 93 degree-days (DD) > 12.7°C, which coincides with the early pink bud stage. This marks a key point in the fire blight epidemic, as it signals the beginning of pathogen spread in the orchard. After a bacterial infection event occurs, symptoms can typically be predicted within + 1-2 days using an interval of 103 degree-days (DD) > 12.7°C from the event date.

### CONCLUSIONS

The use of the Maryblyt system has enabled the timely identification of key infection periods, such as the activation of active inoculum from overwintering cankers and the potential infection of flowers and young shoots. For the Gala apple cultivar in Laknas, Tirana, disease symptoms generally appear in April, likely triggered by atmospheric events and mild spring temperatures during this period. Specifically:

- The activation of the inoculum from overwintering cankers occurred when 59.2°C (DD) was accumulated from the green tip stage.
- Symptoms on flowers appeared when 98.3°C (DD) was accumulated from the green tip stage and 52.6°C (DD) from the active inoculum.
- Symptoms on shoots appeared when 158.8°C (DD) was accumulated from the green tip stage and 113.1°C (DD) from the active inoculum.

Care for the management of fire blight disease (*Erwinia*

*amylovora*) should be year-round, but efforts to minimize it should especially be made starting with the development of the host plant and particularly during the sensitive flowering phase.

Annual implementation of control measures at the right moment will serve to continuously reduce the impact of the disease in affected orchards.

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**Contribution of Authors:**

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|-----------------|---|---|
| Dhurata Shehu   | : | Conceptualized the study, designed the methodology, supervised field and lab work, performed data interpretation, and wrote the manuscript. |
| Florie Rexhaj   | : | Monitored the phenological stages of apple trees in the orchard, conducted field observations, and contributed to draft review and editing. |
| Lubjana Mahilaj | : | Processed and analyzed the collected data, conducted the literature review, and contributed to refinement of the research context.          |