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CLIMATE CHANGE AND THE NATURAL INFECTION OF APPLE TREES WITH *ERWINIA AMYLOVORA* BURRILL IN NORTHERN TRANSYLVANIA

Smaranda Doina ROȘU-MAREȘ[1,2], Luminița Antonela ZAGRAI[1], Ioan ZAGRAI[1], Zsolt JAKAB-ILYEFALVI[1], Anca Maria CHIOREAN[1,2], Vasile FLORIAN[2]

[1]Fruit Research and Development Station Bistrita, Drumul Dumitrei Nou 3, Bistrita, Romania
[2]University of Agriculture and Veterinary Medicine Cluj-Napoca, Calea Manastur 3-5, Cluj-Napoca, Romania

Corresponding author email: rmsd_smery@yahoo.com

Abstract

Considering the high level of risks that infection with the bacteria Erwinia amylovora has in apple orchards in Romania, we have undertaken a four consecutive years (2019-2022) investigation in terms of fire blight occurrence. In the experimental plots typical symptoms, such as wilted or necrotic shoots in the form of 'shepherd's crook, were visible for two consecutive years (2021-2022), while flower clusters were not affected. The highest damage degree was observed in 2022, when was recorded the least amount of precipitation in the May-June period, but accompanied by extreme phenomena, such as strong winds. At the same time, during the study, the average daily temperatures in the case of May were the highest in 2022, respectively the second highest, in the case of June, being exceeded only by June 2019. According to our observations, the climate changes in the area, which consist of both the increase of the average annual temperature and the occurrence of some extreme phenomena with greater frequency, are favoring factors to increase the occurrence of Erwinia amylovora and amplify the fire blight symptoms in apples.

Key words*: average temperature, bacterial disease, fire blight, young shoots.*

INTRODUCTION

The apple (*Malus domestica* Borkh.) is one of the most consumed fruit in the world occupying the fourth position (Zhang et al., 2020) and the third in terms of quantity produced worldwide (FAOSTAT, 2024). In 2022, over 95 million tonnes were harvested across the globe (FAOSTAT, 2024). *Malus domestica* belongs to the Rosaceae family and is cultivated in all temperate regions of the world (Lyu et al., 2020). The cultivating area with apple has been growing ever since ancient times and it continues to increase even in the 21st century (Cen et al., 2020) (FAOSTAT, 2024).

Over the last 60 years, apple-growing technology changed from traditional production systems, using widely spaced large trees, to more intensive production systems, using trees closely spaced (Robinson, 2011). This was possible after the creation of the Malling series of dwarfing rootstocks (M.9 and M.26) but came with the disadvantage of an increased susceptibility to fire blight and some of the soil complex diseases (Goh et al., 2001). Another disadvantage is the appearance of more favorable conditions for the development of bacterial pathogens due to a bigger number of branch cuts, that create access points for pathogens as well as the young age of the trees in this type of plantation.

Fire blight is a devastating bacterial disease for a wide spectrum of fruit trees, in particular, cultural plants like apple, pear, and quince but also wild species belonging to the Rosaceae family. It affects more than 180 species of fruit trees and woody plants of the Rosaceae family (Vanneste et al., 2000), causing severe damage to flowers, fruits, fresh shoots, leaves, branches, trunk, and root collar (Aktepe et al., 2022).

The first mention of *Erwinia amylovora* infection as fire blight was made by Burrill in 1880 when he called this disease the anthrax of fruit trees (Burrill, 1880). The disease caused by *Erwinia amylovora* Burrill, was first time reported in 1780 on pear and quince in New York (United States) (Denning, 1974), then it spread worldwide to more than 60 countries

(Gaganidze et al., 2020; Santander et al., 2022). It is very difficult to control the disease because the bacterium has significant pathogenic capacity once it has entered the plant. Fire blight is one of the most damaging diseases of apples because of its destructiveness (Gaganidze et al., 2020).

Due to its high damage potential, *Erwinia amylovora* has had the status of a quarantine organism in many countries around the world. According to the latest information available on the website of EPPO (2024) this status has changed in many countries, such as Switzerland or some European Union members, because it no longer fulfill the criteria for being a quarantine organism. However, this is mainly due to the large area of distribution in those countries, not to a decrease in the disease importance and impact. The same status change also has occurred in Romania and the neighbouring countries. Nevertheless, there are countries such as Kazakhstan (Kairova et al., 2023) and Korea (Song et al., 2021) where *Erwinia amylovora* is still subject to quarantine.

As a result of global warming, the spread of fire blight to the unaffected countries and regions is inevitable (Gayder et al., 2023). In countries like Romania, where it is already present, there are concerns about how climate change is modifying the epidemiology of this disease. In Romania, climate change appears to consist of rising temperatures, amplification of extreme phenomena, and altered precipitation patterns according to the World Bank portal on climate (climateknoledgeportal.worldbank.org), and this pattern is expected to continue in the future.

Variations in environmental conditions are difficult to reproduce accurately and also they impact both the pathogenicity of bacteria and the response of plants to the aggressions of this pathogen (Van der Zwet and Beer 1999). This is also the reason why performing experiments that involve on-field observations is still a valuable tool for recommending the most efficient control strategies.

E. amylovora has high variability in damage occurrence patterns in the orchard because of the specific biology of this bacterium. *E. amylovora* transits from an epiphytic faze of colonization, on the plant surface, to an endophytic infection internally in the plant tissue (Zeng et al., 2021) when environmental conditions are favorable. However, the infection can become visible after 2 to 4 weeks after the epiphytic bacteria arrives in the orchard (Van der Zwet and Beer, 1999). Such behaviour can be one of the causes for high level epidemics even when the meteorological conditions are not optimal for infection.

These are the reasons why we undertaken a multi-year study regarding the natural infections with *Erwinia amylovora* in a temperate region affected by the climate change.

MATERIALS AND METHODS

The epidemiologic study was carried out in an experimental plot owned by the Fruit Research and Development Station (FRDS) Bistrita. It is situated at 47º10' North latitude and 24°30' East longitude in the northern part of Romania, on Bistrita hilly area, at 358 m above sea level. The climate has the characteristics of temperate-continental regions with hot summers and cold winters. The experimental plot consists of an untreated old apple orchard, established by using both Romanian and foreign apple cultivars and different apple hybrids. In this experimental plot, planting distances are 2 m x 4 m resulting a density of 1250 trees/ha. Observation were made on six apple cultivars: ‘Auriu de Bistrita’, ‘Salva’, ‘Jonathan’, ‘Idared’, ‘Goldprim’ and ‘Generos’. Some of these cultivars are known to be susceptible to the infection with *E. amylovora*, such as ‘Idared’ (Sobieczewski et al., 2014) or ‘Auriu de Bistrita’ (Jakab-llyefalvi and Platon, 2012; Militaru et al., 2012), while others such us ‘Goldprim’ have a better behaviour, (Militaru et al., 2012).

The cultivars have been grafted on MM 106 rootstock and the trees were 28 years old when the survey has begun in 2019.

Visual observations have been performed weekly in the summer, from 2019 to 2022 and the symptoms displayed have been noted throughout the four consecutive years.

The meteorological data were graphically processed using the Microsoft Excel platform.

Temperature degree days were calculated as the difference between the average daily temperature and the value of 12.7 degrees Celsius which is the constant value, with the help of which it calculates day degrees for infections with *Erwinia amylovora*. The data thus obtained were summed up to be compared with the thresholds indicated in the MARYBLYT^{TM} model (Steiner, 1990a, 1990b) for favorable conditions for *Erwinia amylovora* infections. Meteorological data were graphically analyzed using the Microsoft Excel platform.

The difference between the frequency of the symptoms on six cultivars during 2019-2022 period were statistically analysed using the One-Way Anova Test on the Microsoft Excel platform The statistical analysis was not continued with the Duncan test since because the differences were not significant.

RESULTS AND DISCUSSIONS

The year 2019 was characterized by the absence of fire blight symptoms on apple cultivars grown in our experimental plot. In all the other three years (2020, 2021, 2022) when the infection occurred, the fire blight symptoms were prevalent on shoots (Figure 1), by expressing the characteristic shepherd's crook shape. Rapidly growing shoots are the second known to be the next most susceptible organ of a plant to *Erwinia amylovora* after the flower (Van der Zwet and Beer, 1999).

Figure 1. Wilting of a shoot, caused by *Erwinia amylovora,* with bacterial exudate on 'Auriu de Bistrita', 22.06.2022. (Original photo)

Although regular inspections were carried out in the orchard both during the flowering period the growth and ripening of the fruits, no symptoms of bacterial fire were observed on the flower clusters and only sporadically on fruits.

Figure 2. Apple fruit infected with *Erwinia amylovora*, showing bacterial exudate forming from the lenticels, 22.06.2022. (Original photo)

The fact that the temperature has continuously increased in the Bistrita area may be a possible cause of the way the *Erwinia amylovora* epidemics manifested in recent years. In all cases, the primary infection appeared only on the shoots and not on the flowers, which has been observed in much southerly areas such as California (Van der Zwet and Beer, 1999).

The average annual temperature in the last 9 years has increased by up to 3 degrees Celsius (Figure 3) compared to the multiannual temperature recorded in the last century when it was 8.2°C in the Bistrita area (Crăciun et al., 1979).

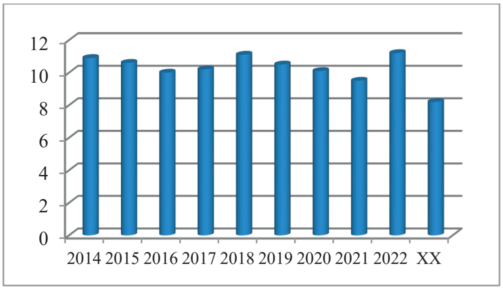

Figure 3. Average annual temperature in the period of 2014-2022 in comparison with XXth century.

The climatic changes in the northern part of Romania are very evident when it comes to the average monthly temperatures during winter months. The evolution of the average monthly temperatures, during November-February (2019-2022), can be seen in the chart of Figure 4. Since the winter temperature can have an impact on how the *Erwinia amylovora* epidemic manifests, We compared the new data to the multi-annual average of the last century (Crăciun et al., 1979). If in November of 2020, the average monthly temperature was the closest to the XXth century average with a difference of only 0.12ºC, in November of 2019, the temperature difference recorded was the largest in comparison to the last century, with a difference of 6.36ºC. Additionally, all other monthly averages were higher than the reference ones, as shown in Figure 4. These averages ranged from 0.74 to 5ºC.

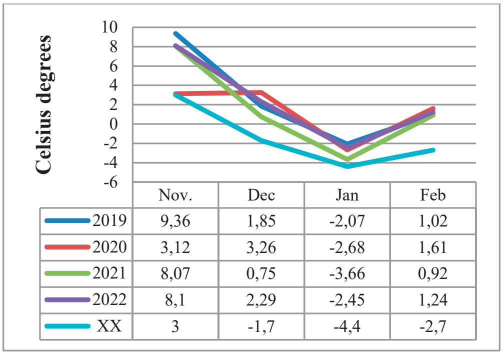

Figure 4. Average monthly temperature in winter months in 2019-2022 and the XXth century multiannual.

During the summer months we noticed that the highest average of monthly temperature in May was in 2022 (Figure 5), the year when *Erwinia amylovora* symptoms occurred with the highest frequency. While the highest average monthly temperature in June occurred in the year 2019, the lowest was recorded in June 2020 across all four experimental years. In all four consecutive years, the temperature exceeded the optimum threshold of 15.6°C for infections if the cumulative conditions for day degree (DD) temperature and humidity are met. Although June 2022 was not the warmest of the four years, the average monthly temperature was still high up to 20.17ºC. May and June were both warmer in 2019 and 2022, but despite these similarities, the way that fire blight manifested in the orchard was different.

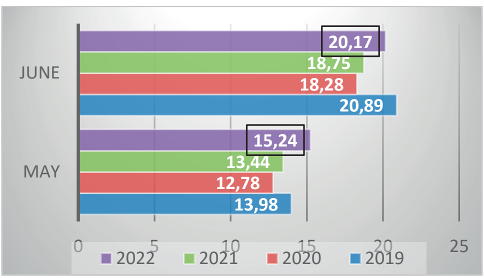

Figure 5. The average monthly temperature in May and June in Bistrita area from 2019 to2022 (ºC)

In June 2022, the average daily humidity was the lowest with a tendency of decreasing towards the end of the month (Figure 6). This possibly led to a more moderate evolution of *Erwinia amylovora* in the orchard. A higher humidity level might have led to a greater degree of damage in apples.

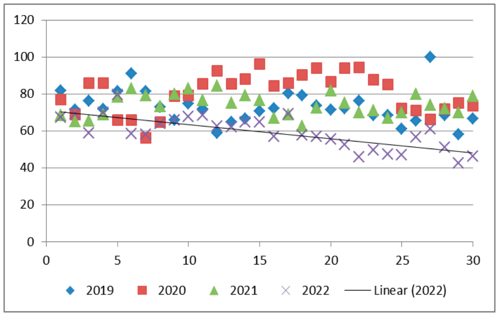

Figure 6. The average daily humidity (%) for the month of June, 2019-2022

Studying the daily average temperatures in May and June and calculating the sum of the day degree (DD) temperature according to the requirements of the MARYBLYT^{TM} system (Steiner, 1990a, 1990b), we found that in all 4 years, the thresholds for the initiation of infections, respectively for the appearance in the orchard, were exceeded only in June (Table 1). This is an explanation of the fact that the infections only manifested during the period of intense growth of shoots. In the Bistrita area, blossom usually occurs at the end of April or in the beginning of May, when the conditions for the initiation and manifestation of the *Erwinia amylovora* infection, according to MARYBLYT^{TM}, are not met.

Table 1. Cumulated day degrees (CDD) for initiation and for infection occurrence in the orchard in Bistrita area (2019-2022)

Year	**∑ DD 12.7 ≥ 106**	**∑ DD12.7≥166**
2019	10 June	16June
2020	15 June	26 June
2021	17 June	23 June
2022	04 June	13 June

Our results are rather different from those obtained by Jakab-llyefalvi and Platon (2012) regarding the appearance and manifestation of the attack of *Erwinia amylovora* on apple trees in the same area.

Unlike the results of the study from 2012, where the first symptoms were on flower clusters, in 2021 and 2022 the damage was present only on shoots. According to Van der Zwet and Beer (1999) this is a typical situation in some years, with optimum conditions for fire blight during the intense growing phase of the shoots and it produces high level damage in a very short period of time. Given the fact that the threshold for infection was surpassed in June in all experimental years during the rapid growth stage of the shoots, it is explainable why this happened.
There is another difference between 2022 and 2012 seasons due to the appearance of a second, smaller infection in most of the cultivars, in September 2022 (data not shown). In 2022, quince (*Cydonia oblonga*) faced a similar situation (Rosu-Mares et al., 2023), possibly due to large amount of precipitation fallen in August and September. It is notable that in the year with the highest rate of fire blight infections, June had the lowest amount of rainfall 18 l/m^2 of all the period analysed (Figure 7).

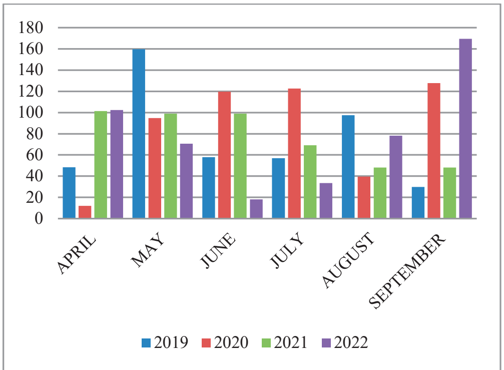

Figure 7. Rainfall (vertical axis, l/m^2) in 2019-2022 growing season, in Bistrita.

Another fact to point out is that the year 2022 had the highest number of rainy days in September and August of all four experimental years (Figure 8).
The frequency of fire blight symptoms occurring on six Romanian and foreign apple cultivars are presented in Figure 9. 'Auriu de Bistrita' was affected in 2021 and 2022, 'Salva' in 2020 and 2021 and 'Jonathan' in 2020 and 2022, while the others were damaged only in 2022.

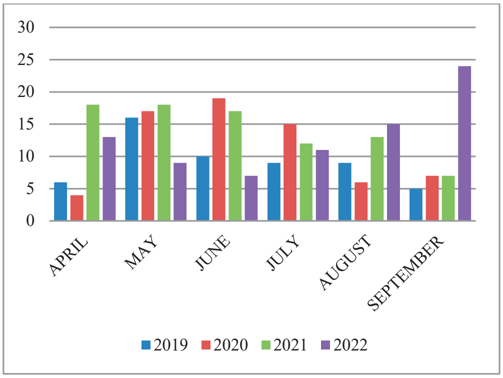

Figure 8. Number of rainy days (vertical axis) in 2019-2022 growing season, in Bistrita.

Although, the Romanian cultivar 'Auriu de Bistrita' suffered the most damage, confirming its susceptibility described by other previous researches (Jakab-llyefalvi and Platon, 2012; Militaru et al., 2012), the damage degrees in our study was lower than the ones mentioned in the other two previous experiments mentioned above.

Table 2. The frequency (F%) of fire blight symptoms on shoots of six untreated cultivars in Bistrita region, (2019 – 2022)

Cultivar/Year	2019	2020	2021	2022
'Auriu de Bistrita'	0	0	3.7	11.4
'Salva'	0	0.5	0.3	0
'Jonathan'	0	1.5	0	1
'Idared'	0	0	0	1.5
'Goldprim'	0	0	0	0.5
'Generos'	0	0	0	0.7

'Goldprim' and 'Generos' were the least affected cultivars by *Erwinia amylovora* followed by 'Idared'. The One-Way Anova Test performed on the data collected in 2019-2022 revealed that there are no significant differences between the cultivars reaction to the infection with *Erwinia amylovora* or between the years.
Overall data of our investigation revealed a lower level of damages caused by *Erwinia amylovora* to the six apple cultivars in the period 2019-2022 when compared with those previously reported Jakab-llyefalvi and Platon, 2012; Militaru et al., 2012). Considering the fact that the experimental plot was untreated, this is an encouraging result, suggesting that the pathogen *Erwinia amylovora* might become

less aggressive in Bistrita region, once the climate changed as was shown.

CONCLUSIONS

The results of four years study revealed that the epidemiological evolution of fire blight in apple orchards varied from no infection in 2019 to a maximum in the year 2022. The results also suggests that the epidemiological patterns of *Erwinia amylovora* have changed and mostly affects young shoots.

This appears to be a consequence of climate changes in Bistrita area, which decreased the epidemicity of *Erwinia amylovora*.

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