Scientific Papers. Series B, Horticulture. Vol. LXX, No. 1, 2026
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

TRENDS IN LATE FROST DAMAGE PROBABILITY FOR PLUM AND SWEET CHERRY IN ROMANIA: A COMPARATIVE ANALYSIS OF 2013-2022 VS. 2000-2009

Ivona Cristina MAZILU[1], Emil CHIȚU[1], Mirela Florina CĂLINESCU[1], Aurelian Florin PLĂIAȘU[1], Lavinia-Mihaela UDREA[1], Daniel ALEXANDRU[2]

[1]Research Institute for Fruit Growing Pitești-Mărăcineni, 402 Mărului Street, Piteşti, Romania
[2]National Administration of Meteorology, 97 Bucharest-Ploiești, 013686, Bucharest, Romania

Corresponding author emails: emilchitu@gmail.com, elacalinescu@yahoo.com

Abstract

Late frost damage probability (LFDP) was analyzed in Romania for plum and sweet cherry by comparing the decades 2013-2022 and 2000-2009, using a patented warning method for late-frost damage in orchards based on phenoclimatic simulation. An uneven spatial gradient of LFDP tendency was observed, distributed between the southern half of the country (from -1 to 1.5% for plum and from -1 to 3% for sweet cherry) and the submontane depressions located in the eastern part of Transylvania (7.5-9%). Although in plum the areas with almost unchanged LFDP occupied the south, east, and partially the west of Romania's territory, for sweet cherry, they were restricted to the south-western part of the country and the coastal area. The increase in the critical minimum temperature exerted an overriding influence on the increase in late frost damage probability for sweet cherry and plum, compared with the phenological advance. The study analyzes the circumstances that led to the increasing LFDP for plum and sweet cherry in the 2013-2022 decade and identifies the areas with increased late frost damage frequency and intensity.

Key words*: climatic accidents, 'Tuleu gras' and 'Germersdorf' cvs., bud swelling, budburst, beginning of flowering, end of flowering.*

INTRODUCTION

In recent decades, scientific interest in late-spring frost has increased in a warming climate context, being associated with phenological advance in species such as apple, pear (Chitu & Paltineanu, 2020), sour cherry (Paltineanu & Chitu, 2020; Mazilu et al., 2025a), sweet cherry, peach, apricot (Jakab-Ilyefalvi et al., 2021; Mazilu et al., 2025b), and plum (Chitu et al., 2008; Butac et al., 2025). In this context, the variability of minimum temperatures during spring has increased and consequently, repeated frost episodes have been reported, while the probability of their overlap with sensitive vegetation stages may even rise (Vitasse et al., 2018; Vitasse & Rebetez, 2018). These situations frequently occur during so-called "false springs", when early warm periods are followed by cold air advections, a situation frequently observed in Europe (Zohner et al., 2020).

Two of the main drivers of European climate variability are the North Atlantic Oscillation (NAO) and the Arctic Oscillation (AO) (Hurrell et al., 2003; Wypych et al., 2017). NAO regulates the intensity of the western circulation over Europe (Trigo et al., 2002; Hurrell et al., 2003), influencing either the transport of milder oceanic air during its positive phase or the intrusion of cold air towards Central and Eastern Europe during its negative phase (Trigo et al., 2002; Chamberlain et al., 2021). AO reflects the stability of the polar vortex (Thompson & Wallace, 1998; Cohen et al., 2014) and the degree to which cold Arctic air remains at high latitudes or may extend over the mid-latitudes in Europe (Cohen et al., 2014; Wypych et al., 2017).

In addition to these mechanisms, spring late frosts are often associated with atmospheric blockages. These blockages, such as the Scandinavian type, favor the cold-air intrusion from northern or northeastern regions into Central and Eastern Europe (Brunner et al., 2017; Kautz et al., 2022). In Romania, the effects of these mechanisms are influenced by the country's position within the intersection of

several regional climate influences (Caian et al., 2019). The eastern and northeastern parts have a more continental character, with larger thermal amplitudes and more frequent cold-air advection (Caian et al., 2019), conditions that favor the occurrence of late spring frost.

Oceanic influences are mainly felt in the west and central region, generally associated with higher temperatures and increased precipitation (Caian et al., 2019), reducing the radiative frost events frequency and intensity. Warm and moist airflows can cross the Southern Carpathians. In the south, they are often associated with higher minimum temperatures and fewer frost events (Dima, 2014). In the southwest, Sub-Mediterranean influences are associated with warmer, cloudier, or rainy conditions, which tend to limit nocturnal radiative cooling and, in turn, reduce the intensity of late frosts. In the southeast, the Pontic influence moderates thermal amplitudes. Frost events are therefore generally less frequent and less severe, as night-time temperatures remain higher (Bosneagu et al., 2022; Manea & Grigorescu, 2024). Last but not least, the complex relief of the Carpathians strongly influences the distribution of late frosts, acting both as a barrier to the circulation of air masses and as a factor in their redistribution. Within and at the contact with the Carpathian arch, favorable conditions for the accumulation of cold air frequently occur in depressions and at the valley bottoms, where persistent thermal inversions and cold-air pooling episodes can occur (Rusz, 2015; Micu et al., 2016). The advected cold air may become trapped/stagnant, strengthening local frosts, especially in depressions (as in the Transylvanian Plateau) and the Subcarpathian sector. Recent frost episodes, as in the springs of 2017, 2020 (Mazilu et al., 2025b), and 2025, illustrate how Romania's climatic and

aims to establish the main contributing factors to the increased late frost damage,geographical particularities can favor severe late frost episodes in fruit-growing regions.

Given that these events are difficult to predict, especially over the long term, the present study (LFDP) for plum and sweet cherry during the 2013-2022 decade, compared with the previous 2000-2009 interval, identifies the regions where late frost damage has become more frequent and intense.

MATERIALS AND METHODS

Phenological data and phenophase probabilities. This study used phenological observations made for sweet cherry ('Germersdorf' cv.) and plum ('Tuleu gras' cv.), which differ in phenological timing, with sweet cherry reaching sensitive stages earlier than plum. The choice of the cultivars was motivated by the availability of long-term phenological data (49 years), which is essential for the development and validation of phenological models. Both cultivars are traditional and have been widely cultivated in Romania and, therefore, are representative of pedoclimatic conditions in the main fruit-growing regions. Although they do not fully represent the actual varietal structure, they provide a robust dataset to analyze the climate-phenology relationships and the impact. Phenological stages, bud swelling (51 BBCH), bud burst (53 BBCH), beginning of flowering (61 BBCH), and end of flowering (69 BBCH), were recorded according to the BBCH scale described by Meier (2018). A multiannual minimum, maximum, and average daily temperatures (together with their standard deviations) database for 28 agrometeo-rological stations in areas representative of fruit growing in Romania was also used to calculate the occurrence date/probability of each of the four phenological phases using the mathe-matical model and the methodology proposed by Chitu & Paltineanu (2006) and Chitu et al. (2008; 2011). The study focused on 2000-2009 and 2013-2022 periods, with data resulting from standardized interdisciplinary projects developed.

Late frost damage probability. Critical temperature thresholds used to define frost damage for sweet cherry and plum were adopted from Murray (2020) and integrated as input parameters in the LFDP calculation. These thresholds were -3.9°C (sweet cherry) and -6.7°C (plum) for 51-53 BBCH, -2.8°C for 53-61 BBCH, -2.2°C for 61-69 BBCH, and -1.5°C for the post-flowering period. The late frost damage probability (LFDP) was calculated with a patented warning method, following the methodology previously established and improved by Chitu & Paltineanu (2006), and Chitu et al. (2011) for 2000-2009 and 2013-2022

decades. Therefore, a dynamic analysis of the frost-damage probability tendency was presented.

Minimum temperature, phenology, and late frost damage probability trend and correlations. The 5-day minimum temperatures trend was also obtained as the difference between the above-mentioned decades, and the overlap with sensitive phenological stages was assessed.

The dynamics of the maximum 5-day probability of minimum critical temperatures recorded after the pentad in which, in 50% of the years, the onset of the four phenophases was reached was calculated in order to use a biologically relevant reference for frost risk assessment. This threshold better represents the presence of sensitive organs at orchard scale an avoid inclusion of early intervals, with incipient phenophase and limited exposure to damaging temperatures.

The study performed a comprehensive evaluation of the intensity of the correlations between phenophase occurrence date and their critical minimum temperature with late frost damage probability. The research further explored the contribution of the minimum critical temperature dynamics to the increasing late frost damage probability.

Statistical analyses were conducted using IBM SPSS Statistics 20. Pearson correlation coefficients were also calculated in SPSS to assess the relationships between variables, while linear regression models were developed in Microsoft Office Excel to determine the trends in critical minimum temperature and phenology and their influence on the dynamics of late frost damage probability. All data were presented in the manuscript. Statistically significant differences were explicitly indicated where applicable.

RESULTS AND DISCUSSIONS

I. Comparative analysis of the late frost damage probability in sweet cherry between the decades 2000-2009 and 2013-2022

As shown in Figure 1, during the 2000-2009 period, the country-averaged late frost damage probability (LFDP) for sweet cherry was 10.6%. It ranged from a minimum of 2.3% (corresponding to one damaging frost event in over 50 years), recorded in isolated areas of southeastern Romania, to a maximum of 36.3% (damage occurring more frequent than once every 3 years) in the eastern part of the Transylvanian Plateau.

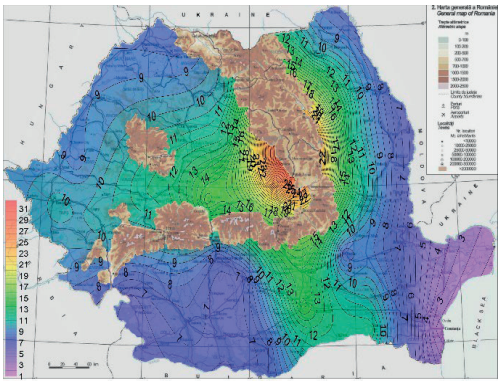

Figure 1. Spatial distribution of LFDP for sweet cherry in Romania between 2000 and 2009

Most of the territory showed LFDP values between 7-10%, although regional differences led to spatial gradients of damage probability. In the western part of the country, damaging frosts could occur once every 10-11 years, while in the southern areas their frequency increased (one event every 7-10 years). Exceptions were observed in the southeastern extremity, where the minimum LFDP values were recorded, and east, where damaging late frosts occurred once every 7-10 years, while more frequent damaging events occurred in the submontane regions, every 4 years. These differences reflect regional climatic influences and local topo-climatic effects.

During the 2013-2022 decade (Figure 2), the spatial distribution of LFDP generally followed a similar pattern, although important differences appeared. The average LFDP increased to 13.4%, and most values ranged from 10% to 15%. At the same time, the variation amplitude increased, with the minimum LFDP decreasing to 2.0% (in the extreme south-east) and the maximum values reaching almost 47% (a damaging frost almost every 2 years) in the east of the Transylvanian Plateau. Additionally, a new area of elevated frost risk was identified in the east, extending from the submontane areas, where frost occurrence rose to 28% towards Iasi (LFDP 15-16%).

The most critical changes were observed in the central part of Romania, where areas with one late frost every 7 years were drastically reduced, forming only a narrow peripheral band towards its western margin.

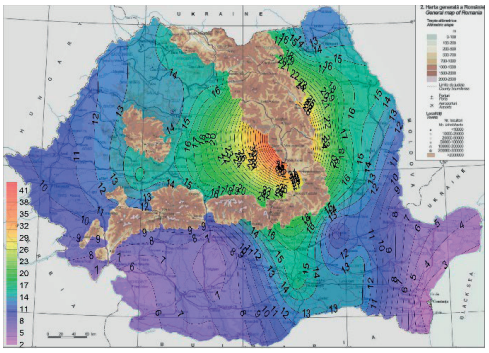

Figure 2. Spatial distribution of LFDP for sweet cherry in Romania between 2013 and 2022

The Transylvanian Plateau showed a sharp LFDP gradient (16-47%, e.g., frosts occurring every 2-6 years) oriented from west to east.
Overall, most regions experienced relatively small LFDP increases (by 0-2 percentage points, as presented in Figure 3).

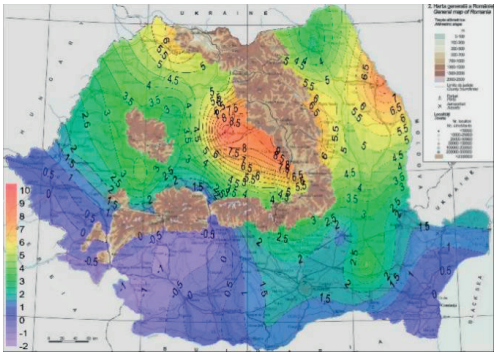

Figure 3. Spatial distribution of LFDP tendency for sweet cherry in Romania (difference between 2013-2022 and 2000-2009)

However, a spatial contrast in damage probability was observed between the southwest (with only a slight decrease in LFDP, especially around Drobeta-Turnu Severin and Targu Jiu) and the northeast (with increases in the LFDP of 8 percentage points around Iasi). The highest LFDP intensity was centered in the east of the Transylvanian Plateau, where both high LFDP values and their strong positive trend were noted. This increase is consistent with a higher frequency of minimum critical temperatures.

II. Comparative analysis of the late frost damage probability in plum between the decades 2000-2009 and 2013-2022

In plum, during the 2000-2009 period (Figure 4), LFDP was 6%, which corresponded to damaging events occurring less frequently than once every 16 years. LFDP ranged from 1.2% (approximately one event every 80 years) in the extreme southeast to 22% (more frequent damaging frost than once every five years) in the eastern Transylvanian Plateau. Most frequently, LFDP values clustered around 5.5%, indicating a relatively lower frost risk than sweet cherry, likely due to later phenological development.
Spatial variability of LFDP was less pronounced in the west and south-west of Romania (5-7% and 3-6%, respectively), although more pronounced in the other regions (1-8% in the south-east and 3-12% in east), the most pronounced LFDP gradient was observed in the Transylvanian Plateau (5-22%), a region is prone to both cold air accumulation and continental air advection.

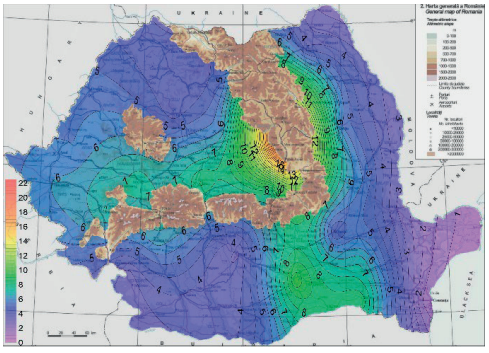

Figure 4. Spatial distribution of LFDP for plum in Romania between 2000 and 2009

Similar to sweet cherry, a secondary core of risk was clearly delineated in the east of the Romanian Plain (7-10%), a region where cold air advection is more frequent. During the decade 2013-2022 (Figure 5), the average LFDP increased slightly to 7%, compared with the previous period, while its maximum values reached the threshold of 36% in the east of the Transylvanian Plateau. Low LFDP values (1-4%) were observed across larger areas of the Romanian Plain, while in the extreme south-

east, as well as in the south of the Western Plain, LFDP remained approximately stable (Figure 6).

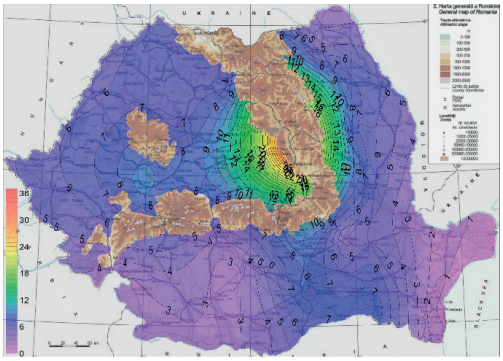

Figure 5. Spatial distribution of LFDP for plum in Romania between 2013 and 2022

LFDP increased in the last analyzed decade by 6-14 percentage units, especially in the risk-prone regions. Low increases in LFDP were observed in the northwest, towards Baia Mare (+ 2.5 percentage points) and in the east, towards Iasi (+2 percentage points).

However, despite this increase in late frost risk, most of the country showed almost stable or even slightly decreasing LFDP values (by 1.2 percentage points), located particularly across a broad area between the southern half of the Timis Plain and Mangalia.

III. Influence of phenology dynamics and 5-day mean of daily minimum temperatures on the increase in the late frost damage probability

a. Dynamics of late frost damage probability across phenological stages BBCH 51-53, 53-61, 61-69, and post-BBCH 69

Comparing the 2013-2022 and 2000-2009 decades, an increase in the average damage probability, higher for sweet cherry (1.03% vs. 0.55% for plum), was observed. This difference may be explained by the higher sensitivity of sweet cherry to negative minimum temperatures and by its earlier phenological development. These characteristics increase the probability of overlap between sensitive phenological stages and critical damaging temperatures.

Nevertheless, significant differences were recorded between the four phenological intervals.

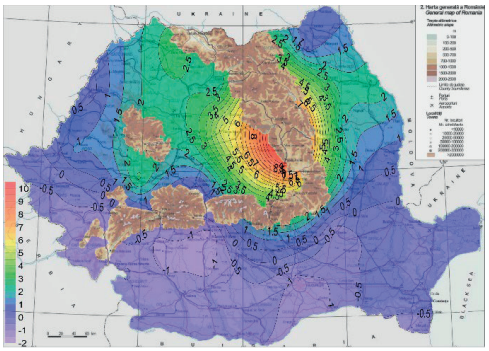

Figure 6. Spatial distribution of LFDP tendency for plum in Romania (difference between 2013-2022 and 2000-2009)

The most pronounced increase in LFDP was observed for BBCH 51-53 (2.78% for sweet cherry and 0.53% for plum) and post-BBCH 69 (0.85% in cherry and 0.96% in plum), while a lower LFDP increase was recorded for BBCH 61-69 (0.56% and 0.55%, respectively). The lowest LFDP variation was found in BBCH 53-61 (-0.07% and 0.17%, respectively), although these values differed significantly from those reported for BBCH 51-53 and post-BBCH 69. These results indicated that late frost risk varied between phenophases, was species-dependent, and was not uniformly distributed across the spring season. To identify the statistically significant drivers of LFDP changes, further analyses regarding phenological dynamics and minimum critical temperature dynamics were performed.

b. Phenological dynamics

The analysis of the average onset date of the four phenophases across 28 representative localities in the decade 2013-2022 highlighted a phenological advance compared to 2000-2009.

Sweet cherry showed an average phenological advance of 3.2 days (5 days for BBCH 51 and 3 days for the BBCH stages 53, 61, and 69), while plum exhibited a slightly greater advance of 3.7 days (4 days for BBCH stages 51, 61, and 69 and only 3 days for BBCH 53).

However, these phenological shifts alone could not justify the observed increases in LFDP, suggesting that other factors, particularly the temporal variability of minimum temperatures, may play a dominant role in frost risk.

Although plum showed a slightly greater advance, its phenological development remai-

ned later than that of sweet cherry. Consequently, sweet cherry stages, especially flowering, are more likely to occur earlier in the season, when the probability of critical minimum temperatures is still relatively high, while the later development of plum may reduce its exposure to early-season cold events.

These interspecific differences in timing did not translate into a consistent effect on LFDP across all phenophases. Phenological advance influenced frost risk mainly during flowering, when sensitive stages overlapped with periods of increased occurrence of critical minimum temperatures.

The increase in LFDP between the two decades was not uniformly distributed across phenophases and followed different patterns. In sweet cherry, the most pronounced increase occurred during bud swelling, whereas in plum it was highest after flowering, followed by flowering, suggesting that the main frost risk window occurs earlier in the season for sweet cherry and later for plum.

Because both species exhibited similar phenological advances, these differences cannot be attributed only to phenological shift, nor solely to differences in temperature sensitivity. Instead, they suggest that LFDP dynamics result from the interaction between phenological timing and the temporal distribution of critical minimum temperatures.

c. Dynamics of minimum 5-day temperatures

In 14 of the 24 analyzed pentads, the minimum temperatures increased, and in 10 pentads they decreased, following a highly irregular temporal distribution (Figure 7).

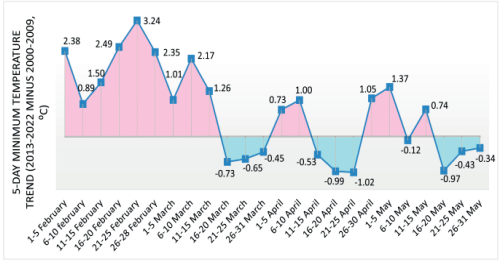

Figure 7. Dynamics of minimum 5-day temperatures from 2000-2009 to 2013-2022

The highest increases, exceeding 2°C, were recorded in four pentads in February and in the second pentad in March. Smaller increases, of 1-2°C, were also recorded in February, March, April, and May. Such warming of minimum temperatures would generally reduce frost risk even under a phenological advance of 3-5 days. However, two periods showed a 5-day minimum temperature decrease of up to 1.02°C. In the first period (the last three pentads of March), temperatures dropped by 0.73°C, while in the second period, between April 11 and 25, temperatures decreased by up to 1.02°C. The April cooling is critical, as it overlapped with the most sensitive stages in both species: flowering (BBCH 61-69) and young fruit (post BBCH 69). Therefore, the increase in LFDP can be primarily explained by this increasing exposure to late frost events of sensitive phenophase, rather than phenological advance alone.

d. The dynamics of the maximum 5-day probability of minimum critical temperatures recorded after phenophase onset

This indicator also increased in the decade 2013-2022 compared with 2000-2009 by 1.55% for sweet cherry and only by 0.72% for plum (both differences were statistically significant at $P \leq 0.05$), indicating a higher probability of damage after the onset of sensitive stages. The probability of critical minimum temperatures associated with the four phenological intervals followed a similar increasing pattern, present in stages BBCH 61-69 (on average, + 2.05%) and BBCH 51-53 (on average, + 1.99%), reflecting increased exposure to critical temperatures during flowering and bud swelling. The differences observed between species (+3.21% during bud swelling and +1.97% during flowering for sweet cherry; +0.76% during bud swelling and +2.13% during flowering for plum) indicate the role of phenological timing, which influences the degree of exposure to critical minimum temperatures.

Post-BBCH 69, further increases of 1.78% and 1.44%, respectively, were recorded. In contrast, the probability of critical minimum temperatures decreased by 0.74% in sweet cherry and by 1.44% in plum during BBCH 53-61, indicating a temporal window with reduced frost risk just before flowering.

Overall, these patterns suggested that both phenological shift and minimum critical temperature variability influenced frost risk.

e. The contribution of the influence of the phenology dynamics and the critical minimum temperatures to the increase in the late frost damage probability

The increase in the late frost damage probability was strongly associated with the increase in the probability of critical minimum temperatures rather than with the phenological advance.

In sweet cherry (Figure 8), LFDP increased in all four phenological intervals, positively correlated with the increase in the incidence of critical minimum temperatures. The intensity of these relationships increased from early stages (51-53 BBCH, R^2=0.2813**) to a maximum during flowering (R^2=0.7642***) and remained substantial after fruit set (R^2=0.5191***), suggesting that frost risk becomes increasingly controlled by minimum temperature variability as floral organ sensitivity increases.

In contrast, phenological advance displayed a significant effect only during flowering (R^2=0.223**), indicating a limited effect of phenological advance.

A similar pattern was observed in plum (Figure 9), where LFDP variation was moderately explained by critical minimum temperatures in early phenological stages (R^2=0.2391** and R^2=0.2326**), but showed a stronger relationship during and after flowering (R^2=0.63693*** and R^2=0.47977***, respectively). Although earlier flowering caused a significant increase in the probability of frost damage (R^2=0.354***), its effect was weaker compared to the critical minimum temperatures. Overall, these results demonstrated that LFDP appeared to be largely driven by the timing and frequency of critical minimum temperatures. Phenological advance became relevant only when the temporal coincidence between flowering and cold-air periods is extended.

The spatial distribution of the late frost damage probability reflected the interaction between cold-air advections on a regional scale, the frequency of critical minimum temperatures, external climatic influences, and topo-climatic features of the relief (Bogdan et al., 2010; Caian et al., 2019).

During the 2000-2009 period, the maximum LFDP values for both species were concentrated in the east of the Transylvanian Plateau, while moderate values characterized the remaining parts of Transylvania, the eastern edge of the Sub-Carpathians, and the southern sector descending toward the Danube.

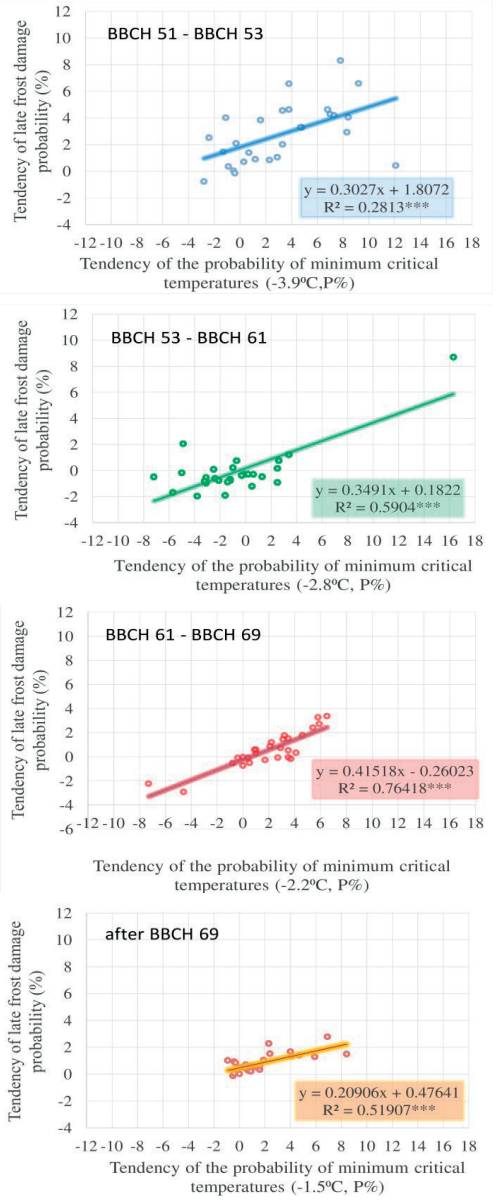

Figure 8. Correlation between LFDP trend and the minimum critical temperatures tendency for sweet cherry (mean of 2013-2022 decade minus that of 2000-2009)

In the Transylvanian Plateau (with high to highest LFDP), the depressional character allows cold-air accumulation through nocturnal radiative cooling, temperature inversions, and cold-air pooling (Geiger et al., 2009).

Meanwhile, intermittent cold-air advection from the north and northeast, with cold-air drainage from the slopes, enhances the accumulation of cold air in valley bottoms, intensifying the occurrence of critical minimum temperatures (Bogdan et al., 2010; Caian et al., 2019) In the east and southeast, increasing LFDP gradients reflect the exposure of the Romanian Plain to advective frost events due to cold-air intrusions from the north and northeast, facilitated by the open relief (Bogdan et al., 2010), which allows the rapid intrusion and spatial expansion of cold-air masses compared with wind-protected regions.

In northeastern regions, higher LFDP values and their increase in the last decade are associated with the predominance of advective frosts driven by northern cold-air masses and facilitated by regional open relief, while wind conditions limit the formation of stable temperature inversions.

In contrast, in the southwestern part of Romania, the low LFDP values are likely related to the sub-Mediterranean influences and the foehn effects produced when moist air masses from the north-western sector cross the Carpathians and reach the south in the form of warmer and drier air masses (Dima, 2014).

In these circumstances, reduced occurrence of the minimum critical temperatures in spring is expected.

In the coastal area, low LFDP could be attributed to the Black Sea influence, which reduces the thermal amplitude and diminishes the frequency of critical minimum temperatures in spring, thereby lowering the incidence and severity of late frosts (Bosneagu et al., 2022; Manea & Grigorescu, 2024). During 2013-2022 decade, high-risk regions intensified.

Comparable trends in spring minimum temperatures have been reported by Mazilu et al. (2025a). The evolution of LFDP, therefore, appears to be linked, at least in part, to increasing critical minimum temperatures. Overall, the spatial distribution of LFDP reflects a transition between radiative frost regimes in intra-Carpathian depressions (Transylvanian Plateau) and advective frost regimes in the eastern part of Romania, with mixed processes in submontane areas (Geiger et al., 2009; Caian et al., 2019).

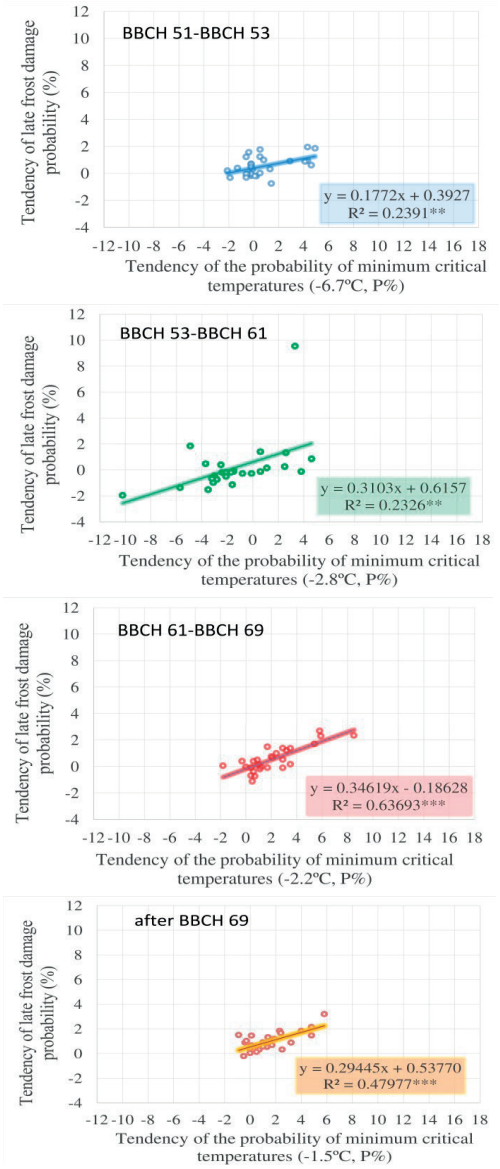

Figure 9. Correlation between LFDP trend and the minimum critical temperatures tendency for plum (mean of 2013-2022 decade minus that of 2000-2009)

CONCLUSIONS

The study performed a comprehensive analysis of the late frost damage probability in two stone fruit species, sweet cherry ('Germersdorf' cv.) and plum ('Tuleu gras' cv.), under recent climate change conditions in Romania. LFDP was higher in sweet cherry.

This was mainly related to a greater exposure to critical minimum temperatures, while advances in flowering seem to play a secondary role. Spatially, high-risk areas remained concentrated, especially in the eastern part of the Transylvanian Plateau, where both the highest values and the strongest increasing trends are observed. At the opposite pole, lower and more stable LFDP values were observed in the southern and western areas, suggesting that regional climatic influences and topoclimatic conditions shape frost risk.

This study shows that the increase in LFDP during 2013-2022, relative to 2000-2009, was mainly driven by the increase in the probability of critical minimum temperatures, rather than by phenological advance. This relationship was statistically significant for both species and across all phenological stages, reaching its maximum intensity during flowering.

Although significant phenological advances were observed (up to 5 days in sweet cherry and 4 days in plum), their influence on frost damage probability was limited and became significant only when flowering coincided with periods of increased occurrence of critical minimum temperatures.

The distribution of frost risk across phenophases differs between species. In sweet cherry, LFDP tends to increase during early stages, while in plum the increase occurs later. These differences reflect a shift in the timing of sensitive periods relative to cold events.

Overall, the study provides new evidence that changes in late frost risk in Romania are more strongly linked to temperature dynamics than to phenological advance alone, highlighting the need to integrate phenological data with detailed analyses of minimum temperature variability to improve frost-risk assessment.

The results are relevant for selecting site-adapted cultivars and improving frost protection strategies. Still, the relative role of critical minimum temperatures and phenological advance may differ between regions, and this needs to be explored further at the regional scale.

ACKNOWLEDGEMENTS

This research work was carried out with the support of the Ministry of Agriculture and Rural Development and was financed from Sectoral Project ADER 6.3.3/2023 ‘Updating the zoning of fruit species in relation to climate changes in Romania’ and the Project ADER 6.3.23/2023 ‘The use of autonomous energy systems for digitalization of technological sequences specific to precision fruit growing’.

REFERENCES

Bogdan, O., Niculescu, E., & Marinica, I. (2010). *Clima României*. Editura Academiei Române.

Bosneagu, A., Manea, A., & Dumitrascu, M. (2022). The influence of the Black Sea on thermal variability in southeastern Romania. *Atmosphere*, 13(5), 789. https://doi.org/10.3390/atmos13050789.

Brunner, L., Hegerl, G.C., & Steiner, A.K. (2017). Connecting atmospheric blocking to European temperature extremes in spring. *Journal of Climate*, 30(2), 585–594. https://doi.org/10.1175/JCLI-D-16-0518.1.

Butac, M., Militaru, M., Nicolae, S., Maresi, E., Chivu, M., Togan, G. (2025). Select the plum genitors for resistance to late spring frost. *Fruit Growing Research*, Vol. XLI, 2025. https://doi.org/10.33045/fgr.v41.2025.02.

Caian, M., Busuioc, A., Birsan, M.-V., Marmureanu, A., Paraschiv, S., & Caian, M. A. (2019). Late-Spring Severe Blizzard Events over Eastern Romania. *Atmosphere*, 10(12), 770. https://doi.org/10.3390/atmos10120770.

Chamberlain, C.J., Cook, B.I., Morales-Castilla, I. and Wolkovich, E.M. (2021), Climate change reshapes the drivers of false spring risk across European trees. *New Phytol*, 229: 323-334. https://doi.org/10.1111/nph.16851.

Chitu, E. & Paltineanu, C. (2006). Phenological and Climatic Simulation of the Late Frost Damage in Cherry and Sour Cherry in Romania. *Acta Hortic*. 707, 109-117. https://doi.org/10.17660/ActaHortic.2006.707.13.

Chitu, E., Paltineanu, C. (2020). Timing of phenological stages for apple and pear trees under climate change in a temperate-continental climate. *International Journal of Biometeorology*, 64, 1263–1271 (2020). https://doi.org/10.1007/s00484-020-01903-2.

Chitu, E., Sumedrea, D., & Paltineanu, C. (2008). Phenological and climatic simulation of the late frost damage in plum orchard under the conditions of climate changes forseen for Romania. *Acta Hortic*. (ISHS), 803. https://doi.org/10.17660/*ActaHortic*.2008.803.17.

Chitu, E., Sumedrea, D., Chitu, V., Topor, E., Paltineanu, C., Dumitru, M.L., Ionita, A.D. and Filipescu, L. (2011). Phenological and climatic modelling of the late frost damage in apricot orchards under the changing climatic conditions of south-eastern Romania. *Acta Hortic.* 919, 57-64. https://doi.org/10.17660/ActaHortic.2011.919.7.

Cohen, J., Screen, J. A., Furtado, J. C., Barlow, M., Whittleston, D., Coumou, D.,Francis, J., Dethloff, K., Entekhabi, D., Overland, J., & Jones, J. (2014). Recent

Arctic amplification and extreme mid-latitude weather. *Nature geoscience*, 7(9), 627-637.

Dima, V. (2014). Foehn over the Eastern Carpathians, characterised by a western circulation of anticyclonic shade. Case study, 4-6 February 2011. *Revue Roumaine de Géographie/Romanian Journal of Geography*, 58(1), 17–27. https://www.rjgeo.ro/issues/revue_roumaine%2058_1/dima.pdf.

Geiger, R., Aron, R. H., & Todhunter, P. (2009). *The climate near the ground* (7th ed.). Rowman & Littlefield. ISBN-13: 978-0742555600.

Hurrell, J. W., Kushnir, Y., Ottersen, G., & Visbeck, M. (Eds.). (2003). The North Atlantic Oscillation: Climatic significance and environmental impact. *American Geophysical Union*. https://doi.org/10.1029/134GM01.

Jakab-Ilyefalvi, Z., Guzu, G.M., & Moldovan, C. (2021). Phenology of sweet cherry cultivars under the climate change events at Bistrita fruit region of northern Transylvania, Romania. *Scientific Papers. Series B, Horticulture. Vol. LXV*, No. 2, 2021.

Kautz, L.-A., Martius, O., Pfahl, S., Pinto, J. G., Ramos, A. M., Sousa, P. M., & Woollings, T. (2022). Atmospheric blocking and weather extremes over the Euro-Atlantic sector - A review. *Weather and Climate Dynamics*, 3, 305–336. https://doi.org/10.5194/wcd3-305-2022.

Manea, A., Dumitrașcu, M., & Grigorescu, I. (2024). Black Sea influence on temperature variability and extreme events in southeastern Romania. *Atmosphere*, 15(2), 245. https://doi.org/10.3390/atmos15020245.

Mazilu, I.C., Chitu, E., Calinescu, M., Plaiasu, F., Septar, L., Jakab-Ilyefalvi, Z., Sirbu, S., & Oltenacu, C.V. (2025b). Dynamics of climatic accidents during peach, apricot, and cherry dormancy and first growth stages in the last 20 years in Romania. *Scientific Papers. Series B. Horticulture*, 69(2).

Mazilu, I.C., Chitu, E., Calinescu, M.F., Plaiasu, F.A., Udrea, L.-A., & Alexandu, D. (2025a). Trends of sour cherry late frost damage probability in the last 25 years in Romania. *Fruit Growing Research*, Vol. XLI, 2025, pp. 39-52. https://doi.org/10.33045/fgr.v41.2025.04.

Meier, U. (Ed.). (2018). Growth stages of mono- and dicotyledonous plants. *BBCH Monograph*. Julius Kühn-Institut (JKI), Quedlinburg 2018. https://doi.org/10.5073/20180906-074619.

Micu, D.M., Dumitrescu, A., Cheval, S., & Birsan, M. V. (2016). Climate of the Romanian Carpathians. *Springer International Pu*. https://doi.org/10.17378/AWC2015_51.

Murray, M. (2020). Critical Temperatures for Frost Damage on Fruit Trees. https://extension.usu.edu/productionhort/fruit/tree/CriticalTemperaturesFrostDamageFruitTrees.pdf (Retrieved March 10, 2026).

Paltineanu, C., & Chitu, E. (2020). Climate change impact on phenological stages of sweet and sour cherry trees in a continental climate environment. *Scientia Horticulturae*, 261, 109011. https://doi.org/10.1016/j.scienta.2019.10901.

Rusz, O. (2015). Temperature inversions in Transylvania. *Air and Water Components of the Environment*, 2015, 388–395. https://doi.org/10.17378/AWC2015_51.

Thompson, D.W.J., & Wallace, J.M. (1998). The Arctic Oscillation signature in the wintertime geopotential height and temperature fields. *Geophysical Research Letters*, 25(9), 1297–1300. https://doi.org/10.1029/98GL00950.

Trigo, R.M., Osborn, T.J., & Corte-Real, J.M. (2002). The North Atlantic Oscillation influence on Europe: Climate impacts and associated physical mechanisms. *Climate Research*, 20(1), 9–17. https://doi.org/10.3354/cr020009.

Vitasse, Y., & Rebetez, M. (2018). Unprecedented risk of spring frost damage in Switzerland and Germany in 2017. *Climatic Change*, 149(2), 233–246. https://doi.org/10.1007/s10584-018-2234-y.

Vitasse, Y., Schneider, L., Rixen, C., Christen, D., & Rebetez, M. (2018). Increase in the risk of exposure of forest and fruit trees to spring frosts at higher elevations in Switzerland over the last four decades. *Agricultural and Forest Meteorology*, 248, 60–69. https://doi.org/10.1016/j.agrformet.2017.09.005.

Wypych, A., Ustrnul, Z., Sulikowska, A., Chmielewski, F. M., & Bochenek, B. (2017). Spatial and temporal variability of the frost-free season in Central Europe and its circulation background. *International Journal of Climatology*, 37(8), 3340-3352. https://doi.org/10.1002/joc.4920.

Zohner, C.M., Mo, L., Renner, S.S., Svenning, J.-C., Vitasse, Y., Benito, B.M., Ordonez, A., Baumgarten, F., Bastin, J.-F., Sebald, V., Reich, P. B., & Liang, J. (2020). Late-spring frost risk between 1959 and 2017 decreased in North America but increased in Europe and Asia. *Proceedings of the National Academy of Sciences*, 117(22), 12192–12200. https://doi.org/10.1073/pnas.1920816117.