RJH Vol. IV, 2023: 133-140
10.51258/RJH.2023.16

The influence of climatic factors on downy mildew in two vineyards from France and Romania

V. Artem[1], A. Ranca[1], M. Cosma[1*], I. Dina[1], A. Hafiane,[2] G. Delanoue[3], and M. Hnatiuc[4]

[1]Research and Development Station for Viticulture and Oenology Murfatlar, Romania

[2]Institute and School of Applied Sciences of Centre Loire Valley, France

[3]French Wine and Vine Institute, France

[4]Maritime University of Constanta, Romania

*Corresponding author e-mail: cmadalinaandreea6@gmail.com

ABSTRACT

The objective of this study was to evaluate the influence of climate variability from the last two years, namely 2021-2022, on the development of the pathogen *Plasmopara viticola* in two vineyards renowned for the quality of their wines, Murfatlar (Romania) and Val de Loire (France). The study was carried out on four grapevine cultivars: 'Sauvignon blanc' and 'Cabernet sauvignon', authorized for the production of CDO Murfatlar wines; and Cot and Chenin, authorized for the production of CDO Touraine wines. The results regarding the appearance and development of the disease on leaves and bunches in different grapevine development stages, on the two variants of the experiments (treated and untreated) highlighted different levels of attack depending on the distribution of precipitation and the evolution of average air temperatures during the vegetation period. The excess rainfall regime in 2021 of 339.3 mm in Murfatlar and 351.8 mm in Val de Loire, and the air temperatures of 20-25°C generated optimal conditions for the spread of disease on the leaves in the untreated variant, reaching a maximum of 48.3% in Murfatlar and 9.5% in Val de Loire during veraison. The disease also spread to the bunches, reaching a maximum of 86.2% in Murfatlar, endangering almost completely the production of grapes. In the case of the variant where phytosanitary treatments were applied, the degree of attack was a maximum of 4%. In 2022, against the background of quantitatively reduced precipitation compared to 2021, with 64.15% in Murfatlar and 45.01% in Val de Loire, the first oil spots were identified in the untreated variant during BBCH 55 (the emergence of inflorescences), having an insignificant spread, reaching a maximum of 8.9% in the cluster compaction phenophase (BBCH 77).

Keywords: *Plasmopara viticola*, air temperature, rainfall, degree of attack, grapevine disease

INTRODUCTION

Downy mildew is one of the most damaging diseases of grapevine (*Vitis vinifera* L.), being caused by the pathogen *Plasmopara viticola* (Rumbolz *et al.*, 2002). The spores overwinter in the soil, on the infected leaves, and the oospores germinate in the spring and produce sporangia. Rain and wind can disperse primary zoospores generated by sporangia on grapevine leaves, which can swim through water droplets and enter the leaf through stomata (Massi *et al.*, 2021). The sporangia production process takes place at night (for at least 4 hours) in conditions of high humidity (95 -100%) and at a favorable temperature (optimum is around 25 °C). The number of infections varies from year to year, primarily depending on climatic factors. In favorable weather conditions, the disease can cause significant losses due to the infection of all the green organs of the grapevine. The worst epidemics occur in years with wet winters and springs, followed by hot summers with occasional rain showers (Gesller *et al.*, 2011). It is necessary to know some meteorological parameters such as temperature, precipitation and relative humidity in order to take preventive measures against the occurrence of the disease, the values of these factors being necessary to determine the incubation period so that immediate action can be taken (Mezei *et al.*, 2022).

The observations carried out over the years, regarding the appearance, spread and evolution in time and space of the main phytopathogenic agents of the grapevine, including grapevine downy mildew (*Plasmopara viticola*), have highlighted different levels of attack, depending on the climatic conditions of each year (Bois *et al.*, 2017), the presence of the inoculum, the history of the disease and the sensitivity of the given cultivars (Tomoioaga, 2013). The traditional monitoring of grapevine diseases involves visual assessments, carried out by specialists, having the disadvantage of being subjective and time-consuming. In recent years, intelligent sensor-based methods have been developed to implement management strategies in precision viticulture (Mahlein, 2016). It is well known that in the effective fight against any disease, the best measure is its prevention. From specialized studies it is known that, for the appearance and development of the pathogen *Plasmopara viticola*, favorable environmental conditions are necessary, namely: minimum temperature of +7.9°C, optimum of +24°C, maximum of +32°C, and nocturnal humidity higher than 60% (Tulbure and Haidarli, 2013). According to other authors (Mezei *et al.*, 2022), the three 10 rule is necessary: shoot length of at least 10 cm, a minimum of 10 mm of precipitation in 24–48 hours and average daily air temperature equal to or greater than 10 °C. Persistent rain, high humidity and average daily temperatures above 11-14 °C are essential for primary infection cycles. Secondary infections only occur if the primary infection has already spread. The spread of the primary infection is directly observed in theform of so-called "oil spots" on the leaves. Secondary infection can only occur in favorable conditions during the night: high humidity, wind and temperatures over 12 °C (Kennely *et al.*, 2007).

Most of the current disease management strategies include the application of appropriate phytosanitary products (copper-based fungicides or systemic fungicides, etc.). The application of treatments generally follows a fixed calendar, which results in a series of unnecessary treatments and significant costs, also producing a negative impact on human health and the environment (Mahlein, 2016). A current approach in precision agriculture involves using accurate data about environmental conditions (climate, soil or plants) and predicting periods of infection. Accurate data can enable timely warnings for both primary and secondary infections (Zia-Khan *et al.*, 2022).

Understanding and anticipating the impact of biotic factors on plants is necessary in order to assess how diseases and pests may affect agriculture in the future, so that adaptations of cultivation technologies can be suggested according to plantation requirements to minimize crop losses (Altimira *et al.*, 2019).The purpose of this work was to evaluate the influence of climate variability from the last two years, namely 2021-2022, on the development of the pathogen *Plasmopara viticola* in two vineyards renowned for the quality of their wines, Murfatlar and Val de Loire.

MATERIALS AND METHODS

Experimental site

The study was carried out on four grapevine cultivars for white and red wines: 'Sauvignon blanc' and 'Cabernet sauvignon', authorized to obtain quality wines with Controlled Designation of Origin (CDO) Murfatlar, Romania (SCV); and Cot and Chenin, with the CDO Touraine, France (IFV) in two consecutive years: 2021 and 2022.

The vineyards in the Murfatlar wine center were established after 2009, on Berlandieri x Riparia rootstock, selection Oppenheim 4, clone 4 (SO4-4). The rows have a N-S exposure, with a planting distance of 2.2 m between rows and 1.2 m between vines, with a density of 4132 vines/ha, bilateral cordon training system, and a stem height of 0.8 m. For the experimental lots in Amboise, the plantation was established in 1975 for Chenin and in 1976 for Cot, at a planting distance of 1.5 m between rows and 1 m between vines, the plantation having a density of 6666 vines/ha, the training system being Gobelet.

The experimental scheme was placed in blocks with two variants for the application of phytosanitary treatments: treated and untreated, each variant having 15 vines, in three repetitions. The phytosanitary treatments (systemic and contact) were applied depending on the warnings and the climatic conditions of the year. Thus in 2021, at SVM 7 treatments were applied and 8 in 2022, while at IFV 7 treaments were applied in 2021 and 8 in 2022.

Climate data

Climatic parameters (maximum, minimum temperature and precipitation) were recorded at the weather station iMetos 3.3 (SCV) and the CIMEL weather station operated by Meteo France - the French national meteorological service (IFV).

Monitoring of the pathogen Plasmopara viticola

During the vegetative season in each variant (treated and untreated), once a week, the evolution of downy mildew was monitored in different grapevine development stages, according to the BBCH scale (Lorenz *et al.* 1995). To determine the frequency (F), intensity (I%) and degree of attack (G.A.%) of grape downy mildew, the visual graphic scale with seven levels of disease severity was used for leaves (Buffara *et al.*, 2014,) and for the bunches (Caffi *et al.*, 2010).

RESULTS AND DISCUSSION

Climatic conditions, especially air temperature and precipitation, have an important role on the evolution of the studied pathogen. The evolution of the minimum and maximum temperatures recorded during the vegetation period (April-September) at Murfatlar (SCV) and Val de Loire (IFV) in the two studied years (2021, 2022) are highlighted in table 1. We observe in the months of spring in the case of both vineyards, very large differences (27°C on average) between the minimum (-2.8°C-0.9°C in April and 0.8°C -4.8°C in May) and the maximum temperatures (24 .3°C -27.7°C in April and 25.2°C-30.8°C in May). The summer months (June, July, August) show minimum values in the range of 8.4°C-14.6°C, higher values by at least 2°C at SCV (10.3°C -14.6°C) compared to IFV (8.4°C -12.5°C). Regarding the evolution of maximum temperatures in the summer months, we can observe temperatures higher than 30.6°C, with even temperatures of 39.5°C being recorded in August 2021 at SCV and in June and July 2022 at IFV. In September, the minimum temperatures dropped in the range of 3.9°C -5.4°C and the maximums oscillated in a fairly narrow range between 30.0°C-33.6°C.

Table 1. The evolution of the minimum and maximum temperatures in the two studied grapevine growing areas

Year / Vineyard	2021				2022			
	IFV, France		SCV, Romania		IFV, France		SCV, Romania	
Month/ temperature	Min. Temp.	Max. Temp.	Min. Temp.	Max. Temp.	Min. Temp.	Max. Temp.	Min. Temp.	Max. Temp.
IV	-2,8	26,9	-2,6	24,3	-2,7	23,1	0,9	27,7
V	1,2	25,2	0,8	28,8	4,8	30,6	1,3	30,8
VI	10,6	32,0	10,3	32,6	8,5	39,4	10,3	34,5
VII	11,5	30,6	12,1	37,0	8,4	39,3	11,8	36,0
VIII	9,2	32,2	11,1	39,5	12,5	36,9	14,6	35,9
IX	3,9	31,8	5,4	30,0	4,5	32,1	3,8	33,6
Average during the vegetation period	5,6	29,8	6,2	32,0	6,0	33,6	7,1	33,1

Analyzing the evolution of the average air temperatures in the two studied years, (Figure 1), we can see different values for this parameter when comparing them to the multi-annual average. As we can see, in the year 2021 (a), the values recorded at SCV are significantly higher in the months of July (26.3°C) and August (25.1°C), whereas IFV recorded lower values of 19.5°C in July and 18.7°C in August. We observe the same differences of at least 2°C in 2022 for the summer months between SCV and IFV. From the observations made, we find that in both vineyards, the average air temperatures were higher in comparison to the multi-annual average by 1.5°C to 2.8°C.

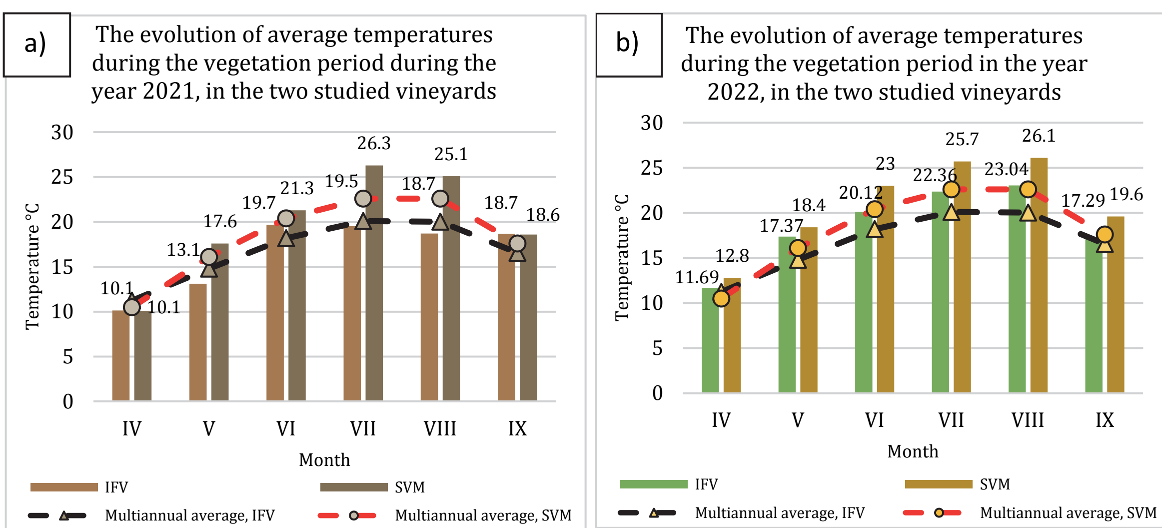

Figure 1. The evolution of average air temperatures compared to the multiannual average

Among the environmental factors, water has a crucial role, being the most important constituent of the vegetative organs of the grapevine, ensuring the many metabolic functions, participating in biochemical reactions and in the transport of synthesized materials and products. The precipitation regime, represented as the number of days with rain, classified according to the amount in three classes (>0.1; >5;>10), are presented in table 2, where we can see that IFV registered in 2021 the highest number of rainy days, especially under 0.1 mm (64 days), compared to SCV, where only 59 days were rainy. In the year 2022 their number was lower, summing 53 days at IFV and 48 days at SCV. Regarding the number of days with over 10 mm of rainfall, they reached a maximum of 7 at SCV in June 2021, while for IFV the maximum was 5 days in June 2022.

Table 2. The evolution of the number of days with rain in the two studied grapevine growing areas

Year/ Vineyard	2021						2022					
	IFV, France			SCV, Romania			IFV, France			SCV, Romania		
	No. of days with rain			No. of days with rain			No. of days with rain			No. of days with rain		
Month	>0,1	>5	>10	>0,1	>5	>10	>0,1	>5	>10	>0,1	>5	>10
IV	5	0	0	14	3	2	13	3	1	8	8	0
V	15	6	3	12	3	2	6	1	1	9	2	0
VI	15	5	4	17	8	7	14	6	5	10	1	1
VII	11	5	2	9	2	2	4	1	0	7	3	2,0
VIII	7	2	0	4	0	0	8	3	0	5	0	0
IX	11	2	1	3	1	1	8	5	3	9	4	2
Total/ vegetation period	64	20	10	59	17	14	53	19	10	48	18	5

Regarding the amount of precipitation recorded during the vegetation period, we observe an uneven distribution. In 2021, periods with excess rainfall (April, May and June) at SCV and (May, June, July, August, September) at IFV alternated with deficit periods (July, August, September) at SCV and April at IFV. In the year 2021, the amount of precipitation was 339.3 mm at SCV and 351.8 mm at IFV, the values being higher in comparison to the multiannual average of 245.7 mm at SCV and 333.3 mm at IFV. For the year 2022, the amount of precipitation recorded was 206.7 mm at SCV and 242.6 mm at IFV, values lower than in 2021 by 64.15% at SCV and 45.01% at IFV.

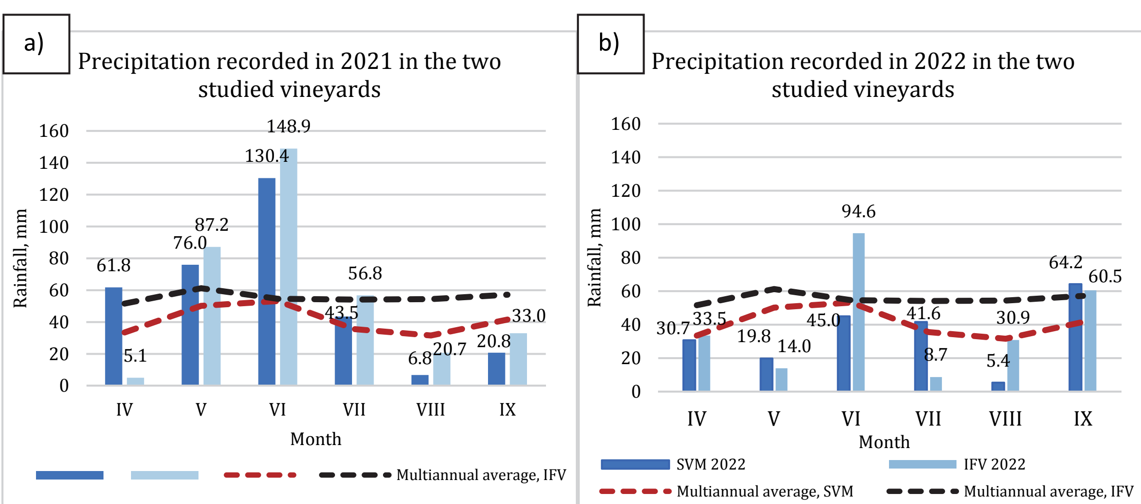

Figure 2. Precipitation evolution in 2021 (a) and 2022 (b) compared to the multi-annual average

Grapevine downy mildew, produced by *Plasmopara viticola*, is a very widespread disease that can produce strong infections during periods of high humidity; the most frequently attacked organs are the leaves, and without the application of phytosanitary treatments the

disease can easily spread to the bunches. Analyzing the evolution of the disease in the studied cultivars during the two studied years, we can see in Figure 3 that at SCV, in the year 2021, the first oil spots appeared on the leaves of the 'Sauvignon blanc' cultivar in the untreated variant, in the phenophase of shoot growth (BBCH 19), the attack spreading slightly in the following stages of grapevine development, reaching a maximum of 27.2% in the stage of berry growth and development (BBCH 73). In the treated variant, the degree of attack showed lower values, recording a maximum of 12.3% during the aforementioned development stage (BBCH 73), the degree of infection in this variant being lower due to the application of phytosanitary treatments. Although the amount of precipitation at IFV in 2021 was higher than at SCV, the degree of attack produced by *Plasmopara viticola* appeared only in the untreated variant, in the BBCH 81 phenophase and was maintained in BBCH 85, with low values of 7.2%. In the case of cultivars for red wines, the disease manifested itself more aggressively in the untreated version, appearing on the leaves at the end of flowering (BBCH 69) and expanding until reaching a maximum of 48.3% during veraison (BBCH 85). In the treated variant, the spread was kept under control, reaching maximum values of 8.8% in BBCH 69. At IFV, the first signs of the disease appeared in the bunch compaction phase (BBCH 77) maintaining a relatively constant value until the veraison stage (BBCH 85), the degree of attack being 8.4-9.5% only in the untreated version.
In the year 2022, characterized by lower precipitation for both of the studied vineyards, the first oil spots were identified at SCV, in the untreated variant during the BBCH 55 stage (inflorescences begin to swell), having an insignificant degree of expansion in the other phenophases. At IFV, the disease manifested itself during the stage of bunch compaction (BBCH 77), reaching values of 8.9% in the untreated version and 1.6% in the treated version. The lack of precipitation in the following period led to the cessation of infection spread in the vineyard.

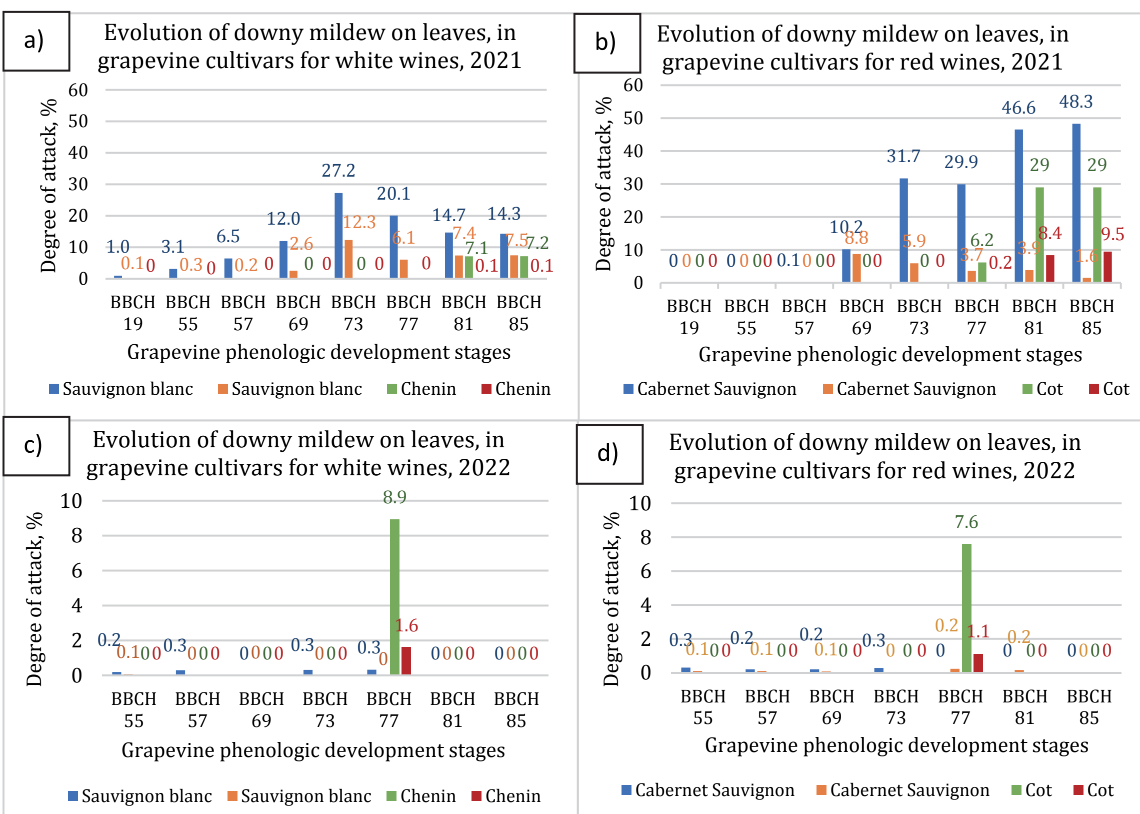

Figure 3. The evolution of downy mildew on leaves in the conditions of the year 2021, for white (a) and red (b) grapevine cultivars; and in 2022, for white (c) and red (d) grapevine cultivars.

Regarding the grapes, the first infections produced by *Plasmopara viticola* in the year 2021 at SCV, were manifested in the untreated variants, at the end of the flowering phenophase (BBCH 69), the values being 27.6% for the Sauvignon blanc' cultivar and 32.2% for 'Cabernet sauvignon', as can be seen from Figure 4. The disease spread in the following development stages, the values reaching a maximum of 86.2% in the veraison stage (BBCH 85) in the 'Cabernet sauvignon' cultivar, endangering the production of grapes. In 2022, the values of the degree of attack of downy mildew at SCV were much lower compared to 2021, the values being for both cultivars in the range of 1.1-1.8%. Higher values were recorded during the stage of bunch development (BBCH 73). At IFV, in 2021, the disease settled in the untreated variant at the end of flowering (BBCH 69), the degree of attack for both cultivars oscillating in a fairly narrow range between 3.4-9.4%, while in 2022, the degree of attack in the case of both cultivars showed a maximum value of 7.7-8.1% during the bunch compaction stage (BBCH 77).

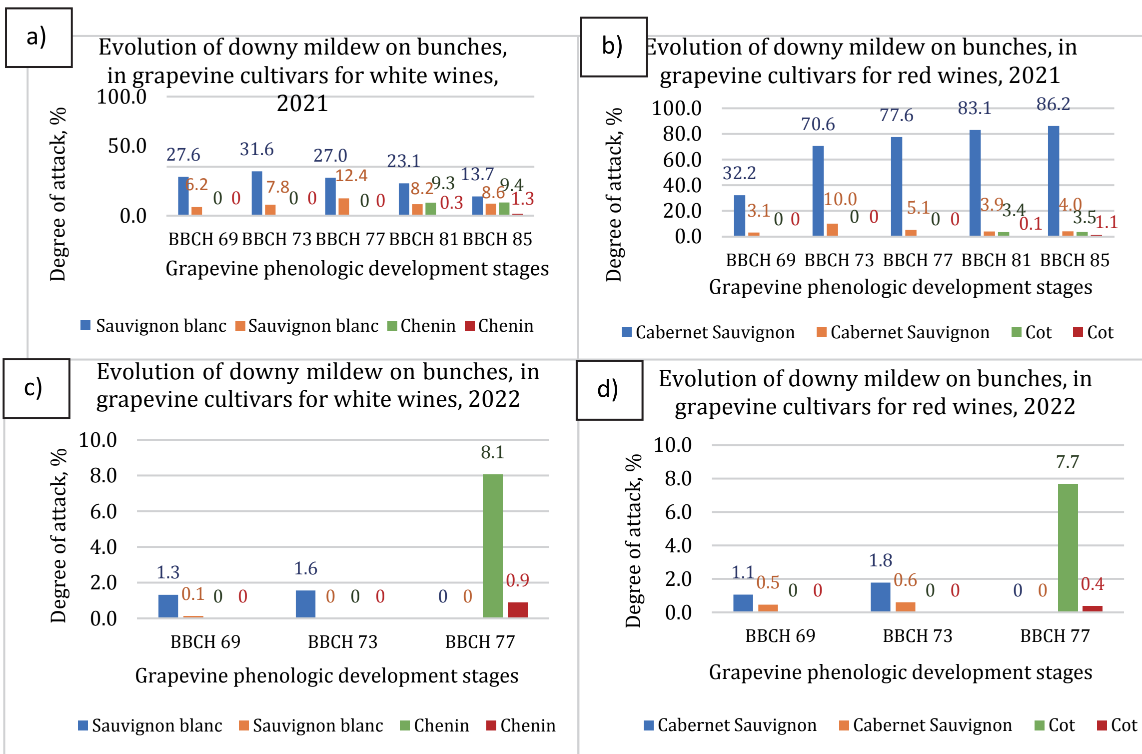

Figure 4. The evolution of downy mildew on bunches in the conditions of the year 2021, for white (a) and red (b) grapevine cultivars; and in 2022, for white (c) and red (d) grapevine cultivars.

CONCLUSIONS

The climatic conditions of the two studied years had a decisive role regarding the establishment and evolution of pathogens, in this case *Plasmopara viticola*. The year 2021, characterized as a rich year from a rainfall point of view, with abundant precipitation, showing an uneven distribution during the growing season, with average air temperatures of 20-25°C, ensured favorable conditions for the emergence and development of the pathogen both on leaves and on bunches. In the year 2022, considering the reduced amount of precipitation in comparison with the year 2021, with 64.15% in Murfatlar and 45.01% in Val de Loire, the degree of disease attack was insignificant.

ACKNOWLEDGEMENTS

This study was financed by the COFUND-ICT-AGRI-FOOD-MERIAVINO-2, project number 203, within PNCDI III, funded by national sources (UEFISCDI) and co-funding by the European Union's Horizon 2020 research and innovation program, Grant Agreement number 862665.

REFERENCES

1. Altimira F., De La Barra N. and Rebufel P. (2019). Potential biological control of the pupal stage of the European grapevine moth *Lobesia botrana* by the entomopathogenic fungus *Beauveria pseudobassiana* in the winter season in Chile. *BMC* Res Notes 12, 548
2. Bois B., Zito S. and Calonnec A. (2017). Climate vs grapevine pests and diseases worldwide: the first results of a global survey. OENO one, 51(2), 133-139.
3. Buffara C. R. S., Angelotti F., Vieira R. A., Bogo A., Tessmann, D. J. and Bem B. P. D. (2014). Elaboration and validation of a diagrammatic scale to assess downy mildew severity in grapevine. Ciência Rural, 44, 1384-1391.
4. Caffi T., Rossi V. and Bugiani R. (2010). Evaluation of a warning system for controlling primary infections of grapevine downy mildew. Plant disease, 94(6), 709-716.
5. Gessler C., Pertot I. and Perazzolli M. (2011). *Plasmopara viticola*: a review of knowledge on downy mildew of grapevine and effective disease management. Phytopathologia Mediterranea, 50(1), 3-44.
6. Kennelly M. M., Gadoury D. M., Wilcox W. F., Magarey,P. A. and Seem, R. C. (2007). Primary infection, lesion productivity, and survival of sporangia in the grapevine downy mildew pathogen *Plasmopara viticola*. Phytopathology, 97(4), 512-522.
7. Lorenz D. H., Eichhorn K. W., Bleiholder H., Klose R., Meier U. and Weber E. (1995). Growth Stages of the Grapevine: Phenological growth stages of the grapevine (Vitis vinifera L. ssp. vinifera). Codes and descriptions according to the extended BBCH scale. Australian Journal of Grape and Wine Research, 1(2), 100-103.
8. Mahlein A. K. (2016). Plant disease detection by imaging sensors–parallels and specific demands for precision agriculture and plant phenotyping. Plant disease, 100(2), 241-251.
9. Massi F., Torriani,S. F., Borghi,L. and Toffolatti S. L. (2021). Fungicide resistance evolution and detection in plant pathogens: *Plasmopara viticola* as a case study. Microorganisms, 9(1), 119.
10. Mezei I., Lukić M., Berbakov L., Pavković B. and Radovanović B. (2022). Grapevine Downy Mildew Warning System Based on NB-IoT and Energy Harvesting Technology. Electronics, 11(3), 356.
11. Rumbolz J., Wirtz, S., Kassemeyer H. H., Guggenheim R., Schäfer E. and Büche, C. (2002). Sporulation of *Plasmopara viticola:* differentiation and light regulation. Plant Biology, 4(03), 413-422.
12. Tomoiagă, L (2013). Ghidul fitosanitar al viticultorului. Academic Press, Cluj Napoca, pp. 143.
13. Tulbure I. and Haidarl I. (2013). Importanţa evaluării factorilor meteorologici în plantaţia viticolă. Noosfera. Revista ştiinţifică de educaţie, spiritualitate şi cultură ecologică, (9), 119-126.
14. Zia-Khan S., Kleb M., Merkt N., Schock S. and Müller, J. (2022). Application of infrared imaging for early detection of Downy Mildew (*Plasmopara viticola*) in grapevine. Agriculture, 12(5), 617.