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RESEARCH ON THE REACTION OF THE CABERNET SAUVIGNON GRAPEVINE VARIETY TO THE VARIABILITY OF CLIMATIC CONDITIONS

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Abstract

Climate change are indisputable, and projections predict an intensification of the effects felt. Viticultural technologies must adapt quickly to ensure the unaltered quality of viticultural production. As a result, studies on the effect of climate change on the intensity of physiological and biochemical processes in the plant, on the quantity and quality of production have represented a priority for many research teams. The present study, carried out at the "Banu Mărăcine" Didactic Station of the University of Craiova, in a wine-growing area located in southern Romania, characterized in recent years by a high incidence of warm temperatures and unevenly distributed precipitation during the growing season, falls within this context. The research highlighted the reaction of the Cabernet Sauvignon variety in 2 years with different climatic profiles that influenced the rate of photosynthesis and transpiration, modified the length of the growing season and the dynamics of the accumulation of synthesized substances, and determined the quality and quantity of production. The results obtained can constitute reference points for establishing technological measures in the case of vineyard plantations affected by climate change.

Key words*: grapevine, climate changes, physiological and biochemical processes, quantity and quality of production.*

INTRODUCTION

The plasticity of the grapevine (*Vitis vinifera* L.) is known, its great capacity to adapt to varied environmental conditions, which has allowed the expansion of grapevine cultivation over large areas, on all continents, in different climatic conditions (Pastore et al., 2022). However, the greater intensity and frequency of extreme weather phenomena attributed to climate change change as a result of global warming, clearly also affects the sustainable cultivation of grapevines (Dejeu et al., 2008; Mărăcineanu et al., 2021).

Climate decisively influences the growth and ripening processes, as it requires appropriate temperatures, durations and intensities of radiation, specific levels of water availability throughout the vegetation cycle, thus influencing the yield, biomass, quantity and quality of production, the specific characteristics of the berries that will ultimately be found in the composition and aroma of the wine (Schultz & Jones, 2010).

In the projections made by the IPCC (The Intergovernmental Panel on Climate Change) on the effects of climate change for the coming years, it is predicted that all major components of the climate system will be affected, each region facing multiple and simultaneous changes (IPCC, 2023).

These climate changes are causing new challenges for viticulture because the quality and quantity of grape production, the timing of ripening, the chemical composition of berries and ultimately the quality of the wine obtained depend essentially on the main climatic factors (Battaglini et al., 2009; Cardell et al., 2019).

The availability and seasonal distribution of water from precipitation, hygroscopicity, solar radiation, temperature and concentration of greenhouse gases (CO_2), the incidence of extreme climatic phenomena are factors with a decisive impact on the quantity and quality of the production obtained (Ruml et al., 2016; Van Leuven et al., 2019; Căpruciu at al., 2022; Cichi et al., 2024).

All climate change projections for the coming period assume an impact on viticulture. In some regions climate change could have beneficial effects on viticulture (for example, extending the boundary of areas favorable for viticulture to

the east and north and into areas with higher altitudes, where temperatures for vines are currently too low), while the impact could be detrimental in other regions due to high temperatures during the grape ripening period that could negatively influence grape quality and wine production (Schultz & Jones, 2010; Bucur & Dejeu, 2016; Arias et al., 2022; Costea et al., 2023).

Each wine-growing region is characterized by a specific natural environment in which climatic conditions, soil characteristics, socio-economic requirements and the skill of the winegrower are the main factors that determine the choice of cultivated varieties and viticultural and oenological practices, thus providing the distinctive character, characteristic for the products of this area, imprinting the character of the terroir (Carbonneau, 2003; Santos et al., 2020).

The ecological conditions specific to each vineyard play a decisive role in determining the varieties cultivated to obtain a production that capitalizes on the specific characteristics of the respective area (Costea, 2006; Ubalde et al., 2010; Dobrei et al., 2018).

Studying the phenology of cultivated varieties can help winegrowers adapt applied technology to climate change, since since the progression of phenophases is extremely closely correlated with temperature (Jones, 2013; Ramos et al., 2020). Changing the duration and advancing the calendar date of the phenological stages as a result of increasing global temperatures can negatively affect the composition and quality of the grapes and therefore the wine obtained (Xenophon et al., 2020; Pastore et al., 2022; Dobrei et al., 2023).

Knowing and monitoring the variability of climatic conditions is particularly important because they cause different reactions, specific to each cultivated grape variety, to which winegrowers must and can react by adapting cultivation technology (Battaglini et al., 2009; Neethling et al., 2017).

MATERIALS AND METHODS

The results of the study presented in this paper were made at the vineyard farm within the "Banu Mărăcine" Didactic Station of the University of Craiova, located in the area delimited for the production of wines with Controlled Designation of Origin (DOC) "Banu Mărăcine". According to the objectives of the research topic, observations and determinations was focused on monitoring the main climatic factors and studying their influence on physiological and bioproductive parameters on the Cabernet Sauvignon variety grafted on the SO4 rootstock (Berlandieri x Riparia Selection Oppenheim 4), semi-tall growth, double cord training methods, spur pruning, 21 buds/plant.

The data for monitoring weather conditions in the 2023 and 2024 years of study and evaluating the effect of climatic conditions come from the weather station located in the vineyard as well as data provided by World Weather Online.

The result of the influence of the variation of climatic resources on the studied variety was evaluated by analysing physiological indicators and bioproductive parameters.

The determination of physiological indicators: the intensity of photosynthesis (A) ($\mu mols/m^2/s$), the intensity of transpiration (E) ($mmols/m^2/s$) was made with Lci-pro equipment during the vegetation period in annual dynamics, in representative phenophases: full flowering, berries pea-sized, beginning of ripening and softening of berries. Other observations and determinations made are specific to the field of study.

The effect of varied climatic resources was evaluated by analysing biological indicators (viability of buds, growth and maturation of shoots) and bioproductive parameters evolution of berry weight (g) and volume (ml), evolution of acidity (g/L H_2SO_4) and sugars of berries during ripening (g/L).

RESULTS AND DISCUSSIONS

Achieving the objectives set for this study could not have been achieved without careful monitoring of the main climatic factors. In order to correctly assess the variation of the recorded values and their effect on the growth and development of the studied variety, the values of the climatic factors from the experimental period are presented in parallel with the multiannual average for the period 2010-2022.

Comparing the average temperatures for the period 2010-2022 (Figure 1) with those from the experimental period, we note that the average

temperature values recorded are higher for both study years. The comparative analysis of the average monthly temperatures recorded in the 2 years of study (Figure 2) reveals that in 2024 the average monthly values recorded were higher than in 2023 by approximately 1°C, a trend observed throughout the vegetation period. If we refer to the month with the warmest temperatures, considered one of the reference values for viticulture, we note the existence of even greater differences between the 2 years of study, especially in terms of the average maximum temperatures: 36°C for 2024 compared to 33°C for 2023.

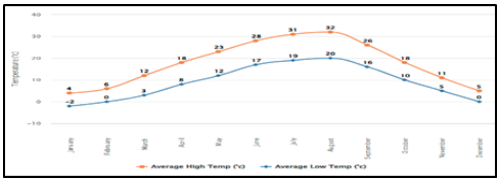

Figure 1. Average monthly temperature - multiannual values (2010-2022)

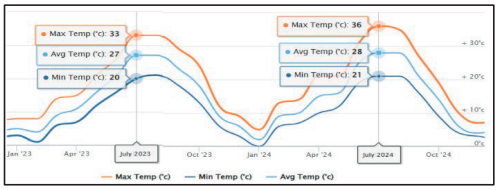

Figure 2. Maximum, average and minimum monthly temperatures from the experimental period

The values of insolation determine the values of temperatures and light intensity and provide information about the favorability of the crop year for vines. Comparing the insolation values, we observe small differences both between the study years and the multiannual values (Figure 3) and between the 2 study years (Figure 4), except for the beginning of the vegetation period (May 2024) when the recorded values were higher than in the same period in 2023.

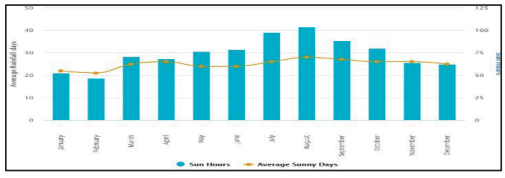

Figure 3. Average Sun hours and Sunny days (2010-2022)

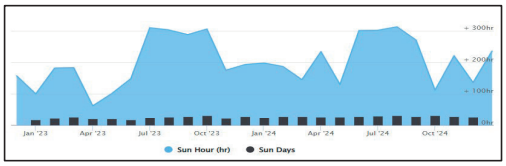

Figure 4. Sun hours and Sun days during the experimental period

Throughout the period we are referring to, the insolation values can be considered very good for the grapevine growth and fruiting processes, being recorded during the vegetation period (April 1 - September 30) 1510 hours in 2023 and 1615 hours in 2024.

To characterize the climatic favorability of the study year, the determination and analysis of data on ecoclimatic indices of precipitation and air hygroscopicity are of particular importance, given their role in the processes of growth, maturation, accumulation of chemical compounds and determination of the quantity and quality of the harvest.

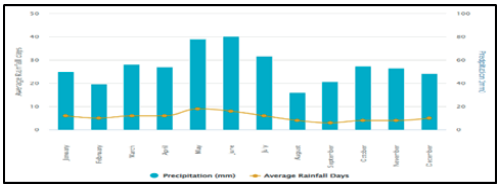

Figure 5. Average rainfall monthly amount and rainy days (2010-2022)

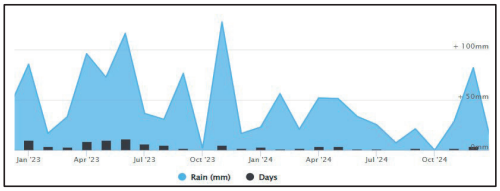

Figure 6. Rainfall amount and rainy days during the experimentation period

The distribution of precipitation in 2023 is similar to the multiannual pattern (Figure 5) with the mention that the amount of precipitation is lower than the multiannual average.

Comparing the volume and distribution of precipitation, the differences between the two study years can be easily highlighted (Figure 6). Overall, in 2023 the amount of precipitation was higher than in 2024, with bigger differences being recorded in May - June, in the phenophases of leaf development, intense shoot growth, flowering, fruit set, and in the late

August - September in the phenophases of ripening of berries (Figure 6).
Therefore, the year 2024 can be described as having a prolonged water deficit between July and September, which is reflected in the reaction of the vines (Figure 6).
The values of atmospheric humidity during the experimental period followed the precipitation distribution curve in the same period (Figure 7).

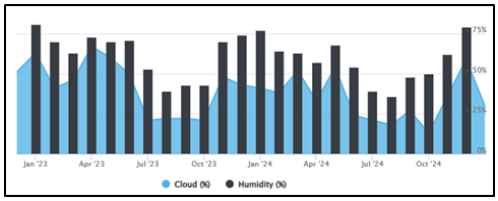

Figure 7. Average monthly atmospheric humidity and nebulosity during the experimentation period

The different climatic profile of the 2 years of study determined a different response of the Cabernet Sauvignon grapevine plants studied.
Determinations regarding the intensity of photosynthesis and transpiration carried out in representative phenophases for the identification of which the BBCH: full flowering (BBCH-65), berries pea-sized (BBCH -75), beginning of ripening: berries begin to develop variety-specific colour (BBCH-81) and softening of berries (BBCH-85), provide provides important information regarding the diurnal and seasonal dynamics of these physiological processes and about the influence of the specific climatic conditions of the year.

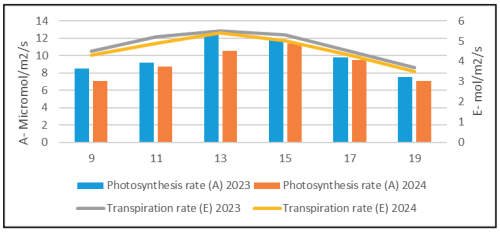

Figure 8. Photosynthesis and transpiration rate at full flowering (in 2023 and 2024)

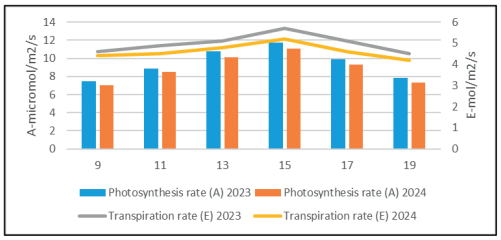

Figure 9. Photosynthesis and transpiration rate at berries pea-sized (in 2023 and 2024)

In the first 2 phenophases in which determinations were made: BBCH 65 - ull flowering and BBCH 75 - berries pea-sized, an almost perfect parallelism between the photosynthesis and transpiration rates in the two years is noted with the observation that in 2024 the determined values were lower compared to 2023, but the differences are not significant (Figures 8 and 9).
The diurnal dynamics of the 2 physiological processes has a diurnal dynamic with a maximum at 1 pm at full flowering (Figure 8) and at 3 pm at the berries pea-sized phenophase (Figure 9). Referring to the seasonal dynamics, the values determined at BBCH 65 and BBCH 75 are close; maximum values of the photosynthesis rate at full flowering at 13:00 were recorded (12.2 µmols/m^2/s) and transpiration rate of 5.6 mmols/m^2/s were recorded compared to BBCH 75 when the determination values were 11.7 µmols/m^2/s and 5.2 mmols/m^2/s, respectively. The parallelism and close values of the rate of physiological processes can be explained by the climatic conditions (regarding precipitation, temperature, insolation) with close values in the 2 years of study.

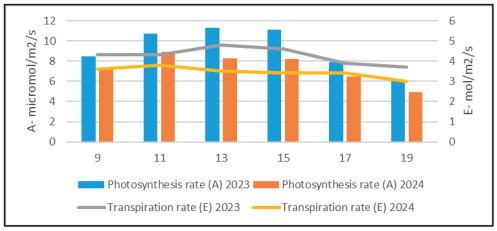

Figure 10. Photosynthesis and transpiration rate at beginning of ripening (in 2023 and 2024)

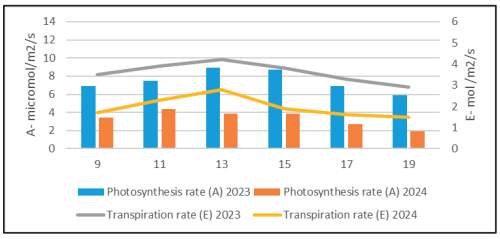

Figure 11. Photosynthesis and transpiration rate at softening of berries (in 2023 and 2024)

In the determinations made at the phenophases beginning of ripening (BBCH-81) and softening of berries (BBCH-85) the differences between the determinations made in the 2 years are higher (Figures 10 and 11), which is due to the completely different climatic profiles in which the respective phenophases took place.

In 2023, the values determined in both the diurnal and seasonal dynamics fall within the normal curve of the two physiological processes, but in 2024, the water deficit as a result of the lack of useful precipitation in August and the deficit of precipitation in September associated with the high temperatures specific to those months negatively influenced the rate of photosynthesis and transpiration. The values determined being only 3.8 µmols/m^2/s and 2.7 µmols/m^2/s (Figures 10 and 11).

Different climatic conditions, specific to the harvest year, determined the different dynamics of berry growth, of the accumulation of substances that determine the quantity and quality of production, highlighted the close dependence between the moment of reaching the maturity stage and environmental conditions, observations demonstrated by the values and dynamics of the bioproductive indices determined, in the period between the beginning of berry coloring and harvest, graphically represented in the Figures12 and 13.

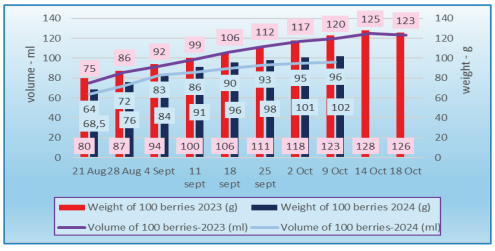

Figure 12. The dynamic evolution of the weight and volume of the berries during maturation

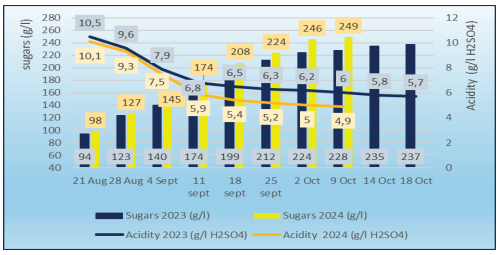

Figure 13. The dynamic of sugar content and acidity of berries during maturation

A first element that is easy to observe by analysing the 2 figures is the different time of completion of the determinations: as a result of the drought during the ripening period and the high temperatures in 2024, the grapes reached maturity and the harvest was carried out about 10 days earlier than in 2023 (on October 9 in 2024, compared to October 18 in 2023).

Another observation derived from the analysis of the results obtained is the influence of climatic conditions on the quantitative characteristics of the grapes; as a result of the water deficit, the berries had a lower weight and volume in 2024 than in 2023 (Figure 12). For example, the weight of 100 berries at the time of harvest was 126 g in 2023 and 102 g in 2024, which leads us to the conclusion that the production obtained in 2024 was significantly lower in quantity than in 2023.

Following the evolution in the dynamics of the qualitative indices, the determinations highlighted the more intense, faster accumulation of sugars in 2024, under the influence of high temperature conditions, lack of precipitation, reduced quantitative production and the reduced duration of the period between veraison and maturation by about 10 days. Under these conditions, at harvest, 249 g/L of sugars and an acidity of 4.9 g/L H_2SO_4 were recorded, while in 2023, under the specific conditions of that year, 237 g/L of sugars and 5.7 g/L of H_2SO_4 were recorded (Figure 13).

The Cabernet Sauvignon variety cultivated at "Banu Mărăcine" demonstrated a high potential for sugar accumulation, the values of this qualitative parameter increasing in 2024 by 151 g/L during the period between veraison and maturation, while in 2023 the sugar content increased by 143 g/L (Figure 13).

CONCLUSIONS

The study demonstrates the determining role of climate on the growth and development of the vine in general and of the Cabernet Sauvignon variety in particular.

The study highlights important results of the variation of climatic conditions, including the modification of phenology and the duration of the vegetation period, influencing the intensity of the development of physiological processes, modifying the dynamics of the accumulation of substances synthesized during the ripening period, all of which ultimately act on the quality and quantity of production.

The Cabernet Sauvignon variety interacted with environmental conditions, expressing its adaptation potential in a specific way.

Knowledge and modeling of these interactions can be a useful tool for planning and applying viticultural practices in current conditions characterized by a high level of variability of climatic conditions from one year to another and even during the same vegetation period.

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