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PHENOLOGICAL CHARACTERISTICS AND PRODUCTIVE POTENTIAL OF THE CABERNET SAUVIGNON (V. VINIFERA L.) VARIETY GROWN UNDER NON-IRRIGATED CONDITIONS

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Abstract. *The favorable combination of soil and climatic conditions in a significant part of Bulgaria, the diverse terrain and presence of suitable microregions create excellent conditions for growing vines and producing high-quality grapes. The study was conducted in the Sub-Balkan viticultural region, under non-irrigated conditions. Climatic conditions during the study period (2022–2024) were characterized by an average annual air temperature of 13.5ºC and an average precipitation of 444 mm. These specific conditions during the growing season affect phenological development, fertility and vines productivity. The period from budburst to technological ripeness of the grapes has an average duration of 167.3 days. The actual fertility was 83.43% and the developed buds from spurs accounted for 92.77%, with an actual fertility coefficient of 1.48. An average of 21.7 bunches per vine were formed, with an average weight of 114.33 g and an average weight of 100 berries of 121.67 g. The yield reached 2.47 kg per vine with a planting density of 3 330 vines per hectare, resulted in a productivity of 8225.10 kg per hectare. The comprehensive assessment shows a good degree of variety adaptation to conditions of limited water supply, outlining its potential for producing wine grapes under similar soil and climatic conditions and creating prerequisites for development and improvement of agrotechnical approaches for sustainable grape production.*

Keywords*: actual fertility, Cabernet Sauvignon, developed buds, fertility coefficient, fruiting shoots, non-irrigated conditions, phenological phases, productivity, yield*

INTRODUCTION

The increased variability of climatic conditions and limitations in water resources underscore the need to investigate the varietal response of grapevines under non-irrigated cultivation. Phenological development, physiological status, yield and grape quality are determined by the combined influence of temperature, water availability and the specific characteristics of a given growing season (CHAVES et al., 2010; HOCHBERG et al., 2017; COOLEY et al., 2017). The grapevine (*Vitis vinifera L.*) is a perennial crop whose development, productivity and quality are shaped by the interaction between the genetic traits of a variety and environmental conditions. Temperature regimes and water availability play a crucial role in phenological development, yield formation and the quality characteristics of the grapes (MOSEDALE et al., 2016; NAULLEAU et al., 2021; VAN LEEUWEN et al., 2024). The phenological development of the grapevine serves as an important indicator for assessing the biological traits, adaptability and production potential of different varieties. The timing and duration of these phenological phases are determined by the genetic characteristics of the variety, as well as the interplay between temperature, precipitation, and cultivation conditions (PARKER et al., 2011). Temperature conditions during the growing season significantly influence the timing of phenological phases and the duration of the period from budburst to harvest.

DUCHÊNE & SCHNEIDER (2005), analyzing long-term meteorological and phenological data from Alsace, observed a shift toward earlier developmental timing and a shortening of the period from budburst to harvest. Regional studies in the Southern viticultural region of Bulgaria provide further insight into phenological development under non-irrigated conditions (STALEV et al., 2024). Research on Cabernet Sauvignon confirms that the response to water deficit depends on its intensity and duration, as well as the specific developmental stage. BASILE et al. (2011) found that the effects of water stress on grapevine physiology and berry composition vary depending on the timing of the stress. COOLEY et al. (2017) also demonstrated that water regime and seasonal characteristics interact to influence berry mass, yield and certain technological quality parameters. In a study on Cabernet Sauvignon, EDWARDS & CLINGELEFFER (2013) found that various deficit irrigation regimes affect growth, water use and yield. Although these results were obtained in irrigated vineyards, they are useful for elucidating the mechanisms by which limited water supply alters the productivity of a given cultivar. The reproductive possibilities of a grapevine is determined not only by the number of bunches but also by the number and mass of the berries within them. In a comprehensive study of ten wine grape varieties, high fertility does not always result in a proportional increase in yield, particularly when the average bunch mass or the individual berries is lower (DRY et al., 2010). According to KELLER (2020), grapevine productivity is the outcome of complex physiological processes influenced both by conditions during the current growing season and by the environment in which the buds were formed during the previous year. Water deficit during the period preceding and throughout flowering can restrict the formation of reproductive organs and successful fruit set. In the post-fruit-set period, water deficit primarily affects berry growth and the accumulation of fresh mass, which can lead to a reduction in bunch weight and overall yield (OJEDA et al., 2001).

The objective of this study is to investigate the phenological characteristics and production potential of the Cabernet Sauvignon variety (*Vitis vinifera L.*) grown under non-irrigated conditions. This involves monitoring key developmental phenophases and evaluating growth and reproductive performance, as well as grape yield and quality parameters. The research aims to determine the variety's adaptive capacity to conditions relying solely on natural water supply and to assess its potential for sustainable production under limited water resources.

MATERIAL AND METHODS

The subject of this study is the red wine variety Cabernet Sauvignon, grafted onto the Berlandieri x Riparia SO4 rootstock and planted in 2005 on the southern slopes of Sredna Gora mountain range. The average altitude of the area is 300 m. The vineyard is in full fruiting, with a planting density of 3.0 m between rows and 1.00 m between vines within the row (3 333 vines per hectare). The vines are trained using a high stem, bilateral cordon system, supported by an appropriate trellis structure. The inter-row spaces are cultivated using a disc harrow.

Cabernet Sauvignon is a late ripening wine grape variety belonging to the Western European ecological-geographical group. The growing tip of the young shoot is sparsely pubescent and intensely pink. The internodes are of medium length and thickness, slightly flattened and somewhat ribbed. The bark of the mature shoot is chestnut-brown, appearing dark violet at the nodes. The pith is small, and the wood is very hard, a characteristic feature of this variety. The buds are small to medium-sized and pointed, with grey-brown protective scales. The leaf blade is medium-sized, five-lobed, thick, and deeply incised; the upper surface is reticulately wrinkled and sparsely pubescent, while the underside is covered with fine, bristly hairs. The leaf is wider than it is long. The upper lateral sinuses are closed, deep to very deep, with an ovoid opening and an acute base or with a triangular opening and a flat base. The petiolar sinus is closed and deep and the leaf appears perforated in five places. The petiole varies in length long, medium or short and is thin, green, with wine-red stripes. In autumn, the

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leaves turn wine-red. The bunch is small, cylindro-conical sometimes winged and compact (Figure 1). The peduncle is short of medium thickness, woody towards the base and tough. The rachis is green. The berries are small and spherical. The skin is blue-black, thick and tough, with an abundant waxy bloom. The flesh (mesocarp) is juicy. The taste is sweet, harmonious and neutral. The variety was included in the official varietal list of the Republic of Bulgaria in 2012 (ROYCHEV, 2012).



Figure 1. Cabernet Sauvignon variety bunch and leaf

During the study period (2022, 2023 and 2024), phenological observations were conducted on the key developmental stages of grapevines throughout the growing season. The duration of the main phenophases is presented in days: sap flow to budburst, budburst to the first leaf appearance, first leaf to flowering, flowering to "pea-size" berry stage, "pea-size" berry stage to véraison (onset of ripening), véraison to technological ripeness and budburst to technological ripeness. For this purpose, normally developed grapevines were selected. The onset of a phase is defined as the day when 5% of the vines have entered that stage; the "mass" onset is defined as 50% of the vines and the end is defined as the point when 95% of the vines have entered the respective stage (BRAYKOV et al., 2005).

The study includes indicators characterizing the actual fertility of the grapevines specifically the percentage of developed buds and the percentage of fruiting shoots as well as the Actual Fertility Coefficient (Cf). These parameters were assessed annually in June on 30 grapevines.

Indicators characterizing grape yield were also examined including: average bunch number per vine; average bunch mass (g); average mass of 100 berries (g); average yield per vine (kg) and average yield per hectare (kg/ha). Phenological observations, the actual fertility and grape yield were assessed according to standard methods described in the Handbook of Exercises in Ampelography (ROYCHEV, 2014).

Climatic data for the study period (2023–2024) were obtained from a meteorological station located within the vineyard. For the three experimental years, data on mean monthly air temperature

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(°C) and precipitation (mm) are presented, characterizing the climatic conditions of the study area (Figures 2 and 3).

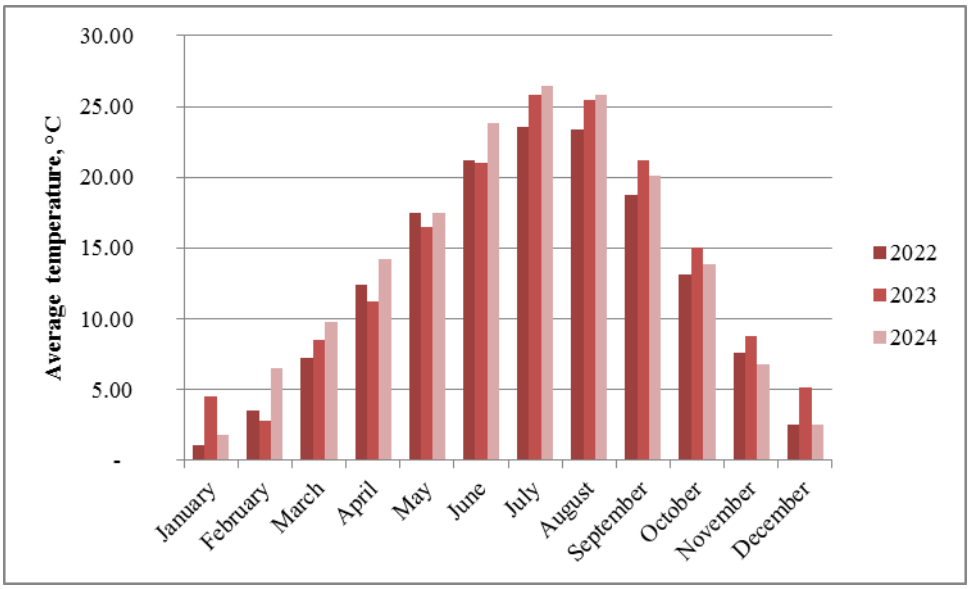


Figure 2. Average monthly air temperature, 2022-2024

The presented data show variation in average monthly temperatures over three consecutive years. From this, one can observe the seasonal temperature pattern, differences between individual years and trends in the temperature regime (Figure 2). The average annual temperatures were 12.66°C in 2022, 13.83°C in 2023 and 14.10°C in 2024. July was the warmest month across the three years, with a maximum value of 26.5°C recorded during the period (in 2024).

Precipitation distribution shows significant variation, both between months and across the individual years (Figure 3). Total precipitation amounted to 414.1 mm in 2022, 448.9 mm in 2023 and 475.8 mm in 2024.

A comparison of these two climatic indicators reveals that 2024 was both the warmest year and the year with the highest total precipitation within the three year period under review.

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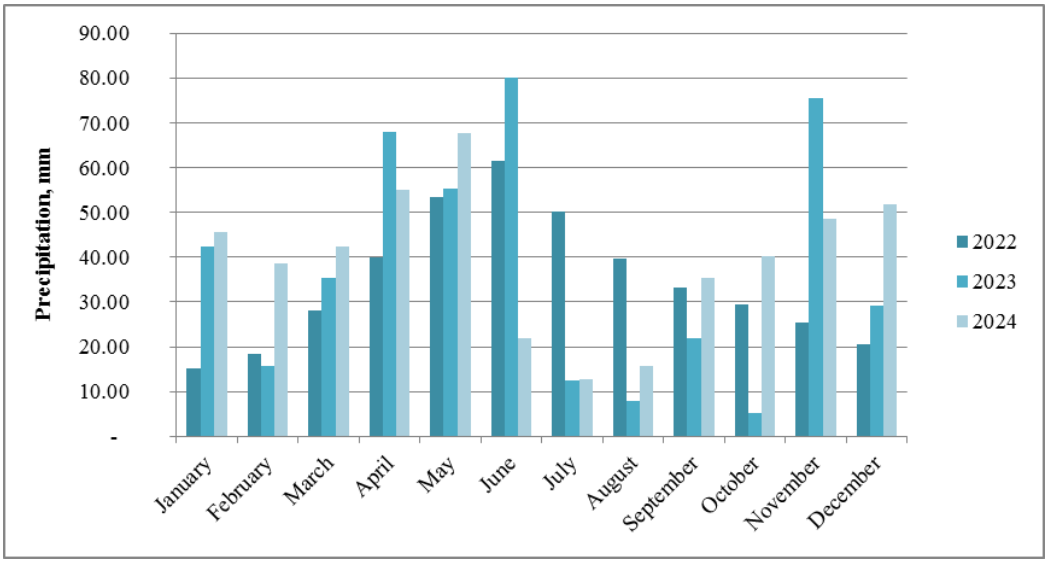


Figure 3. Precipitation, 2020-2022

RESULTS AND DISCUSSIONS

The results reflect the influence of interannual variations in key climatic indicators on the phenological development, actual fertility and productivity of the grapevines. The presented data (Table 1) show the duration of the main phenological phases, which makes it possible to determine the differences between years and specific developmental varietal characteristics.

Table 1

Duration of phenophases in days during the period 2022 - 2024

Year	SAP flow to bud burst	Bud burst to first leaf appearance	First leaf to flowering	Flowering to pea size	Pea size to veraison	Veraison to technological ripeness	Bud burst to technological ripeness
2022	16b	10a	51a	18a	48b	38b	173a
2023	10a	11a	55a	21b	45a	32a	165a
2024	10a	11a	51a	20a	43a	31a	164a
Average	12	10,6	52,3	19,7	45,3	33,7	167,3

The duration of the period from sap flow to budburst was longest in 2022 (16 days) whereas in 2023 and 2024, it was 10 days. The average duration for this period is 12 days. This indicates a more prolonged initial stage of development in 2022, compared to a shorter period in the following two years.

From bud break to the first leaf appearance, the phase lasted between 10 days (2022) and 11 days (2023, 2024), with an average of 10.6 days. From first leaf appearance to flowering, the phase lasted 51 days (2022, 2024) and 55 days in 2023, with an average duration of 52.3 days. From flowering until the berries reached "pea size," the duration was 18 days in 2022, 21 days in 2023 and 20 days in 2024, with an average of 19.7 days. From the "pea size" stage to the onset of ripening

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(veraison), the period decreased from 48 days in 2022 to 45 days in 2023 and 43 days in 2024, with an average of 45.3 days. The duration of the stage from the onset of ripening (véraison) to technological ripeness was 38 days in 2022, 32 days in 2023 and 31 days in 2024, with an average of 33.7 days. The total length of the growing season from bud burst to the attainment of technological ripeness was 173 days (2022), 165 days (2023) and 164 days (2024), resulting in a three-year average of 167.3 days.

The actual fertility of the Cabernet Sauvignon grapevines is a relatively stable metric (Table 2). The average percentage of developed buds is 83.43%, while the percentage of fruiting shoots is 92.77%. The coefficient of actual fertility for the period averages 1.48.

Table 2

Actual fertility during the period 2022 - 2024

Year	Developed buds %	Fruiting shoots, %	Coefficient of actual fertility Cf.
2022	84,28a	94,47a	1,51a
2023	83,93a	92,24a	1,48a
2024	82,10a	91,60a	1,46a
Average	83,43	92,77	1,48

The highest values for the indicators were recorded in 2022 and the lowest in 2024. The variety maintains a relatively consistent capacity for bud development and the formation of fruiting shoots. This stability is a favorable characteristic for regular fruiting of the vines under the specific growing conditions.

The average number of grape bunches per vine decreased from 24 in 2022 to 19 in 2024, while the average mass per single bunch increased from 110 g (2022) to 118 g (2024). The mass of 100 berries remained relatively stable, with an average value of 121.67 g for the period. Despite the increasement in bunch mass, the average yield per vine decreased from 2.64 kg (2022) to 2.24 kg (2024) and the yield per hectare dropped from 8 791.20 kg/ha (2022) to 7 459.20 kg/ha (2024). The average yield for the three-year period was 8 225.10 kg/ha (Table 3).

Table 3

Grape yield during the period 2022 - 2024

Year	Average number of bunches per vine	Average weight per bunch, (g)	Average weight of 100 berries, (g)	Average yield per vine, (kg))	Average yield per ha (kg))
2022	24b	110,00a	123,29a	2,64b	8791,20b
2023	22a	115,00a	120,14a	2,53b	8424,90b
2024	19a	118,00a	121,60a	2,24a	7459,20a
Average	21,7	114,33	121,67	2,47	8225,10

A reduction in the number of bunches per vine is a key factor contributing to the lower yield in 2024. Variety shows relative stability regarding the bunch weight and individual berries, but a decline in quantitative productivity metrics over the period under review.

CONCLUSIONS

Phenological development of the grapevines across the years is characterized by a shortening of the period from bud burst to technological ripeness from 173 days in 2022 to 164 days in 2024 with the most pronounced change occurring during the phase from véraison (onset of ripening) to technological ripeness.

Actual fertility remained relatively constant, with an average of 83.43% developed buds, 92.77% fruiting shoots and an actual fertility coefficient (Cf) of 1.48.

A downward trend was observed in the number of bunches per vine, as well as in the yield per vine and per hectare, despite an increase in the average bunch weight. This identifies the number of bunches as a key component of productivity during the period under review. The weight of 100 berries and the average bunch weight remained relatively stable, indicating that the primary differences in yield are linked mainly to the number of bunches formed, rather than to significant changes in their size.

The practical significance of this research lies in the potential to use these findings to refine cultivation practices for the Cabernet Sauvignon variety under variable weather conditions. In this regard, the results contribute to more informed vineyard management, aimed at stabilizing yields and preserving the technological quality of the grapes required for production of high-quality red wines.

BIBLIOGRAPHY

BRAYKOV D., PANDELIEV, S., MASHEVA L., MIEVSKA T., IVANOV A., ROYCHEV V., BOTYANSKI P., 2005. Viticulture [Students' guide to viticulture]. Academic Publishing House of the Agricultural University, Plovdiv [BG].

BASILE, B., MARSAL, J., MATA, M., VALLVERDÚ, X., BELLVERT, J., & GIRONA, J., 2011. Phenological sensitivity of Cabernet Sauvignon to water stress: vine physiology and berry composition. American Journal of Enology and Viticulture, 62(4), 452-461.

COOLEY, N. M., CLINGELEFFER, P. R., & WALKER, R. R., 2017. Effect of water deficits and season on berry development and composition of Cabernet Sauvignon (Vitis vinifera L.) grown in a hot climate. Australian Journal of Grape and Wine Research, 23(2), 260-272.

CHAVES, M. M., ZARROUK, O., FRANCISCO, R., COSTA, J. M., SANTOS, T., REGALADO, A. P., ... & LOPES, C. M., 2010. Grapevine under deficit irrigation: hints from physiological and molecular data. Annals of botany, 105(5), 661-676.

DRY, P. R., LONGBOTTOM, M. L., MCLOUGHLIN, S., JOHNSON, T. E., & COLLINS, C., 2010. Classification of reproductive performance of ten winegrape varieties. Australian Journal of Grape and Wine Research, 16, 47-55.

EDWARDS, E. J., & CLINGELEFFER, P. R., 2013. Interseasonal effects of regulated deficit irrigation on growth, yield, water use, berry composition and wine attributes of C abernet S auvignon grapevines. Australian Journal of Grape and Wine Research, 19(2), 261-276.

HOCHBERG, U., BONEL, A. G., DAVID-SCHWARTZ, R., DEGU, A., FAIT, A., COCHARD, H., ... & HERRERA, J. C., 2017. Grapevine acclimation to water deficit: the adjustment of stomatal and hydraulic conductance differs from petiole embolism vulnerability. Planta, 245(6), 1091-1104.

VAN LEEUWEN, C., SGUBIN, G., BOIS, B., OLLAT, N., SWINGEDOUW, D., ZITO, S., & GAMBETTA, G. A., 2024. Climate change impacts and adaptations of wine production. Nature Reviews Earth & Environment, 5(4), 258-275.

KELLER, M., 2025. The science of grapevines. Academic press.

MOSEDALE, J. R., ABERNETHY, K. E., SMART, R. E., WILSON, R. J., & MACLEAN, I. M., 2016. Climate change impacts and adaptive strategies: lessons from the grapevine. Global change biology, *22*(11), 3814-3828.

OJEDA, H., DELOIRE, A., & CARBONNEAU, A., 2001. Influence of water deficits on grape berry growth. Vitis-geilweilerhof-, 40(3), 141-146.

NAULLEAU, A., GARY, C., PRÉVOT, L., & HOSSARD, L., 2021. Evaluating strategies for adaptation to climate change in grapevine production–A systematic review. Frontiers in plant science, 11, 607859.

DUCHÊNE, E., & SCHNEIDER, C., 2005. Grapevine and climatic changes: a glance at the situation in Alsace. Agronomy for sustainable development, 25(1), 93-99.

PARKER, A. K., DE CORTÁZAR-ATAURI, I. G., VAN LEEUWEN, C., & CHUINE, I., 2011. General phenological model to characterise the timing of flowering and veraison of Vitis vinifera L. Australian journal of grape and wine research, 17(2), 206-216.

STALEV, B. S., MIHAYLOV, M. T., BAMBALOV, V. G., & IVANOV, V. I., 2024. Changes in the phenological and temperature requirements during cultivation of the Rubin variety in the southern wine-growing region of Bulgaria. Agricultural Sciences/Agrarni Nauki, 16(43), 5.

ROYCHEV, V., 2012. Ampelografiya [Students' guide to ampelography]. Acad. Publishing Agricul.Univ.Plovdiv. [BG].

ROYCHEV, V., 2014. Rakovodstvo za uprazhneniya po ampelografiya. [Students' guide to ampelography]. Acad. Publishing Agricul.Univ.Plovdiv. [BG].