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CLIMATE CHANGE AND ITS IMPACT ON THE COURSE OF BASIC PHENOLOGICAL PROCESSES IN TABLE GRAPE VARIETIES

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Abstract. *Grapevine (Vitis vinifera L.) is among the most valuable and widespread crops in world agriculture, distinguished by its rich varietal diversity and wide economic significance. Within this diversity, table varieties occupy a special place as a crop intended for direct consumption, distinguished by an attractive appearance, balanced taste and high nutritional value. The phenological development of table grapevine varieties is an important indicator of their adaptability to agroclimatic conditions and effective production management in modern viticulture. The present study aims to assess the influence of climatic factors on the course of phenological phases in the local varieties "Super ran Bolgar", "Brestovitsa" and the introduced variety "Italia", grown in the Thracian Lowland region, by applying the unified BBCH scale. The experiment was conducted during two growing seasons (2023-2024). The main phenological stages were monitored: bud burst (BBCH 0:05 - 0:08), leaf development (BBCH 1:11), flowering (BBCH 6:60, 6:61, 6:65 and 6:69), fruit development (BBCH 7:75), fruit ripening (BBCH 8:81 - 8:85) and reaching technological ripeness (BBCH 8:89). The analysis was based on agrometeorological indicators - air temperature and precipitation. The results show that the temperature regime has a significant impact on the speed of transition between the individual BBCH phases, with a tendency to delay with increasing temperature. The variety "Super ran Bolgar" reaches the phases from 8:81 to 8:89 earlier, being characterized by the shortest vegetation period. "Italia" exhibits a longer phenological cycle and higher heat requirements, while "Brestovica" is characterized by intermediate indicators and good adaptability to varying climatic conditions. The obtained results emphasize the importance of the BBCH scale as a reliable tool for standardized assessment of phenological development and provide a scientific basis for optimizing agrotechnical practices and varietal selection in conditions of climate change.*

Keywords*: air temperature; BBCH scale; climate change; table grape varieties; phenological stages; precipitation*

INTRODUCTION

The vine development is closely related to climatic conditions, and phenological processes play a key role in yeild shaping and grape quality. The main phenological phases include bud burst, flowering and veraison (REIS et al., 2022). They are a key indicator of the adaptability and productivity of grape varieties (BERNÁTH et al., 2021). Table grapes are distinguished by specific phenological characteristics that determine their economic value. Depending on the duration of the growing season, they are divided into early, medium-early and late varieties (ROYCHEV & KERANOVA, 2024). Early varieties, such as “Super ran Bolgar” and “Brestovitsa”, have a shorter growing season and lower heat requirements. This makes them suitable for areas with more limited heat resources. On the other hand, the variety "Italia" belongs to the medium-late to late varieties, requiring a significant amount of heat to reach technological ripeness (KÖSE, 2014). Suitable for regions with a warmer climate and a long growing season (Van LEEUWEN & DARRIET, 2016). It is distinguished by good transportability and wide distribution in the wine-growing regions of the world (JONES et al., 2005). The duration of the growing season can vary significantly depending on climatic conditions and

agricultural techniques (KÖSE, 2014). Temperature is the main factor influencing the onset and duration of phenological phases (NISTOR et al. 2024). The base temperature for the start of growing season is around 10°C, with any deviation from this threshold affecting the rate of development (BERNÁTH et al., 2021). Under global warming conditions, a shift of phenological phases by 5 to 10 days earlier is observed (BERNÁTH et al., 2021). Grape ripening by 12 days earlier is reported by FILIMON et al. (2024) and by 15-24 days earlier (COLIBABA et al. 2024) depending on temperature changes, which affects the yield and quality of the product. Water regime and sunlight play an important role, as moisture deficiency can lead to delayed development and lower grape quality (KÖSE, 2014). For a standardized description of phenological stages in modern scientific literature, the BBCH scale (Biologische Bundesanstalt, Bundessortenamt und Chemische Industrie) is widely used, which is a universal decimal system for coding plant development (MEIER, 2018). The adaptation of the BBCH scale for the grapevine was developed by LORENZ et al. (1995), who created a detailed scheme for describing all the main and secondary phenological stages. Their work is considered fundamental, as it introduces standardized codes for the phases from winter dormancy (BBCH 00) to leaf fall (BBCH 99). This classification allows for an accurate and unambiguous description of processes such as bud burst, flowering, berry set and ripening, which greatly facilitates the comparison of results between different studies and geographical regions. In recent decades, the BBCH scale has been widely used in studies related to the influence of climate change on grapevine phenology. A number of authors use BBCH codes to analyze the shift of phenological phases over time, establishing a trend towards an earlier onset of phases such as bud burst and flowering as a result of increasing temperatures (JONES et al., 2005; DUCHÊNE & SCHNEIDER, 2005). Phenological differences between varieties are genetically determined, but are strongly influenced by environmental conditions. Despite the significant number of studies on grapevine phenology, there is a need for in-depth research on table varieties in Bulgarian conditions.

The aim of the study is to assess the influence of climatic factors on the course of phenological phases in the local varieties "Super ran Bolgar", "Brestovitsa" and the introduced variety "Italia", grown in the Thracian Lowland region, by applying the unified BBCH scale.

MATERIAL AND METHODS

Three table grape varieties were used: Super ran Bolgar, Brestovica and Italia, planted in the area of the town of Pazardzhik, Plovdiv region, Southern Bulgaria (295 m average altitude). The vineyard is in full fruiting. The planting distance is 1.40 m between rows and 1.60 m between vines in the row, d total of 4460 vines per hectare. The plants are high-stemmed. The training system is a double cordon with the appropriate trellis. The pruning in all variants include spurs with two buds, a total of 8 spures /16 buds/ per vine. The inter-rows are processed with a milling cutter. The vineyard is grown under non-irrigated conditions.

The Super ran Bulgar is an early ripening table variety. Its grapes ripen in the first week of August. It is one of the significant achievements in grape selection in Bulgaria (Figure 1a). The early ripening period and sufficient yields, combined with the attractive grape appearance and good taste, present it as a promising variety for the domestic and foreign markets.

Brestovica variety is an mid-early ripening. Its grapes ripen in the second half of August. The vines are with vigorous growth, good fertility and high yield (Figure 1b). It is characterized by valuable agrobiological and technological qualities and is widely used in the warmer regions of the country for the production of table grapes for the domestic market.

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Italia variety is a late ripening. Its grapes ripen in the second half of September. Italia is a valuable variety with beautiful bunches and large amber-yellow berries, with sufficient sugars and acids (Figure 1c). The muscat flavor of the berries appears relatively late - when consumer ripeness occurs. Due to its good resistance to low temperatures, it is suitable for stem cultivation. The grapes are with excellent transportability and suitable for storage.

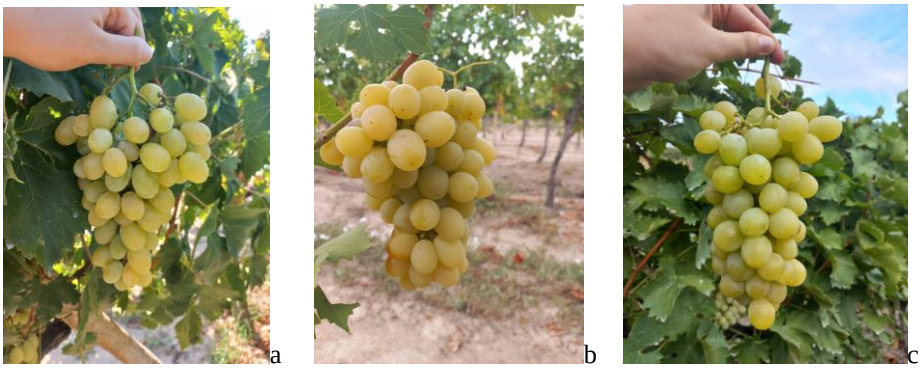

Figure 1. Super ran Bolgar (**a**); Brestovica (**b**); Italia (**c**)

These varieties were included in the official list of the Republic of Bulgaria in 2010 (ROYCHEV, 2014).

During the vegetation of 2023 and 2024, phenological observations of the main stages were carried out for Super ran Bolgar, Brestovica and Italia. For this purpose, normally developed vines that had entered full fruiting were selected. The beginning of the phase is considered to be the day on which 5% of the vines entered it, mass entry - 50% of the vines and the end, when 95% of the vines entered the corresponding phase (BRAYKOV et al., 2005).

The BBCH scale was used to determine the vine phenology. Decimal coding for determining the phenological stages is identified as follows: the first digit indicates the main growth stage, and the second digit indicates the secondary growth stage, corresponding to a serial number or percentage value. In this study, the phenological phases used were: bud burst (beginning, end), first leaf appearance, first inflorescens appearance, flowering (beginning, mass, end), fruit development (pea size) and veraison from beginning to technological ripeness (Table 1).

Table 1

Phenological phases and development with BBCH identification keys for grapevine

Main phases	Stage description	BBCH codes
0: Bud burst/buds development	05 „Wooly bud“: brown moss is clearly visible	0:05
	08 Bud burst: green shoot tips clearly visible	0:08
1:Leaf development	11 The first leaf is open and spreads out to the shoot side.	1:11
6: Flowering	60 The first inflorescens is released from the bud	6:60
	61 Beginning of flowering: 10% inflorescens drop	6:61
	65 Mass flowering	6:65
	69 End of flowering	6:69
7:Berry development	75 Grape berries are the size of a pea	7:75
8: Veraison	81 Beginning of ripening: the berries begin to develop the varietal characteristics	8:81
	85 Berry softening	8:85
	89 Berries are ready for picking	8:89

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Climatic data for the experimental period (2023 - 2024) were taken from the meteorological station located in the vineyard. The indicators of average monthly air temperature (ºC) and precipitation (mm) are presented, which characterize the climatic features of the studied area (Figure 2 and 3).

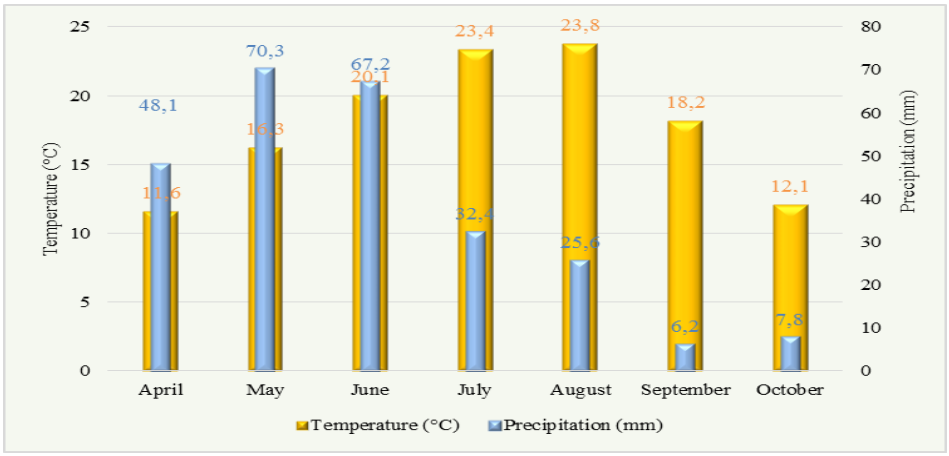

Figure 2. Average temperatures (ºC) and precipitation (mm), April to October, 2023

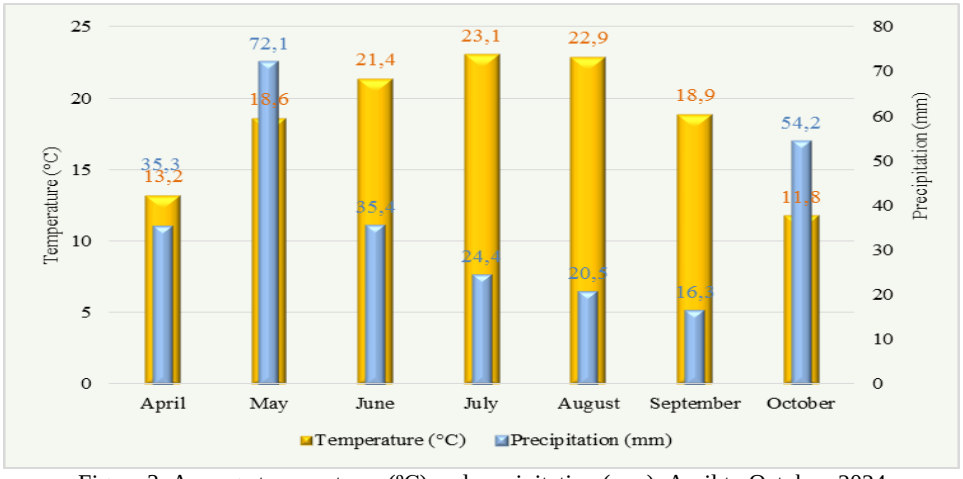

Figure 3. Average temperatures (ºC) and precipitation (mm), April to October, 2024

RESULTS AND DISCUSSIONS

The influence on the normal course of the individual phenophases is exerted by the key climate elements in 2023 (Figure 2) and 2024 (Figure 3): air temperature and precipitation.

Table grape varieties used are characterized by different ripening periods. Analysis on the BBCH scale shows a clearly pronounced interannual variability. In 2024, all observed phases occur earlier compared to 2023, with the shift varying between 5 and 14 days depending on stage and variety (Table 2).

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The most significant shift is observed in the initial phases (BBCH 0:05 - 1:11), where in the Super ran Bolgar variety development begins approximately 8-10 days earlier. A similar tendency is observed in the other varieties (Brestovica and Italia), which indicates a synchronous response to climatic conditions.

The BBCH 6:60 - 6:69 (beginning and end of flowering) also show a shift to earlier dates in 2024 by approximately 10-14 days. This has important agronomic significance, as it shortens the period of sensitivity to adverse climatic conditions, and also affects successful pollination and setting. A relative preservation of the duration of the interval between phases is observed, which suggests that the acceleration is the result of external factors (air temperature), and not a change in internal physiological dynamics. The ripening phases (BBCH 81-89) show a significantly earlier onset in 2024 (by 4-12 days).

There is a clear distinction between the varieties. Italia reaches technological ripeness at the latest (early September), while Super ran Bolgar - already at the beginning of August. This discrepancy is essential for planning and organizing the harvest and market sales.

Table 2

BBCH codes and dates of occurrence of phenological phases during 2023 and 2024

BBCH codes	Year	Super ran Bolgar	Brestovica	Italia
		Date	Date	Date
0:05	2023	04/04	06/04	07/04
	2024	26/03	28/03	30/03
0:08	2023	10/04	11/04	13/04
	2024	01/04	04/04	06/04
1:11	2023	12/04	13/04	15/04
	2024	03/04	06/04	08/04
6:60	2023	16/04	17/04	20/04
	2024	08/04	10/04	12/04
6:61	2023	03/06	05/06	07/06
	2024	20/05	27/05	28/05
6:65	2023	06/06	09/06	10/06
	2024	23/05	01/06	02/06
6:69	2023	11/06	13/06	15/06
	2024	31/05	03/06	05/06
7:75	2023	27/06	29/06	30/06
	2024	07/06	09/06	12/06
8:81	2023	17/07	27/07	10/08
	2024	13/07	20/07	28/07
8:85	2023	31/07	18/08	01/09
	2024	01/08	01/08	22/08
8:89	2023	14/08	25/08	13/09
	2024	10/08	18/08	02/09

CONCLUSIONS

Phenological analysis on the BBCH scale shows a clear influence of climatic conditions on the development of the studied table grape varieties. In 2024, a significant shift of all phenological phases to earlier dates was found compared to 2023, which is an indicator of a faster accumulation of effective temperatures.

Regardless of the interannual variability, the varieties maintain a stable sequence in terms of development, with Super ran Bolgar characterized by the earliest phenology, Brestovica occupying an intermediate position, and Italia the latest.

The difference in harvest dates between varieties reaches 3–4 weeks, which creates an opportunity to extend the period of fresh grape supply. At the same time, interannual climatic conditions have a significant influence, with warmer years (e.g. 2024) observing a delay in the harvest to earlier dates.

These results have important practical significance, as they allow for better planning of the harvest campaign, optimal allocation of labor resources, and increased market competitiveness through a longer presence on the market.

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