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IMPACT OF CLIMATE CONDITIONS ON SOME WHITE WINE VARIETIES WITH INCREASED RESISTANCE TO FUNGAL DISEASES AND LOW WINTER TEMPERATURES

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Abstract

Phenological phases of grape varieties are dynamic and sensitive to climatic conditions. Knowledge of the relationship between climate factors and main phenological phases of grape varieties is of great importance for viticulture and winemaking. The study presents result of phenological observations of three white wine varieties – *Solaris, Muscaris* and *Hibernal*, selected in Germany, characterized by increased resistance to fungal diseases and low winter temperatures. Study was conducted in the period 2024-2025, the vines were grown at the Agricultural university vineyard, located in the Brestnik village. The main goal of the study is to analyze the dynamics of main phenological phases during vine growing season and their relationship with agrometeorological factors. The monitored phases were budding, first leaf appearance, first inflorescence appearance, flowering, berry growth, veraison and the onset of technological ripeness. The duration of each stage and the length of growing season in days were determined. Dynamic indicators used were average air temperature, relative humidity, precipitation and soil parameters including soil moisture and soil temperature. Total and active temperature sum for onset of main phases and the entire growing period has been determined. The results obtained could be used for precise determination for suitable terroirs of the studied varieties depending on the specific technological goals.

Keywords: PIWI, phenology, climate change, vegetation, terroir

INTRODUCTION

The sequence and timing of the vine biological phases– bud burst, flowering, veraison and technological ripeness – is a sensitive indicator of the climatic conditions in the wine-growing regions (Jones & Davis, 2000). The onset and course of the phenological phases is closely related to the climatic conditions, which have a direct impact on the yield and grapes quality (Parker et al., 2013; Molitor et al., 2014). In recent years, changes in their duration have been observed in different grape varieties. According to Duchêne & Schneider, (2005) and Fraga et al., (2016), climate change is mainly expressed in an increase in average temperatures, a change in the precipitation regime and the frequency of extreme events, which leads to a shift to earlier dates. These changes have a direct impact on the yield, grape quality and plant resistance to stress factors. Early harvest due to a warmer period can have an impact on grape composition and therefore quality (Coombe, 1987; Jackson & Lombard, 1993), with significant changes in grape composition, such as sugars, anthocyanins, aromatic compounds and tannins, occurring between veraison and harvest (Bindon et al., 2013; Keller, 2010). According to Bock et al. (2011), climate change is reflected in acceleration of phenological phases – for example, bud burst and flowering occur on average 2 to 4 weeks earlier than in previous decades. The interaction between the vine and its environment is changing – earlier flowering may increase the risk of damage from late spring frosts, and ripening at high summer temperatures may lead to an imbalance between sugars and acids in the beries (Parker et al., 2013). Phenological observations are a key indicator for assessing the adaptation of the vine to climate change. Monitoring the relationships between climatic indicators and vine development is essential for refining varietal selection, the timing of agrotechnical measures and the long-term sustainability of viticultural systems (Molitor et al., 2014).

In the context of changing climate, research on the phenology of resistant varieties is becoming increasingly important for optimizing viticultural practices and adapting viticulture to future climate conditions (Fraga et al., 2016). Climate change requires the search for alternative approaches in breeding and agronomic techniques. One way is to use resistant (PIWI) varieties that are more adaptable to changing conditions and allow sustainable production with minimal pesticide use. Among them are the varieties Solaris, Hibernal and Muscaris, which show promising phenological characteristics, such as early ripening or resistance to climatic and biotic stress, making them subject of increasing scientific interest (Eibach & Töpfer, 2015). The Solaris variety is characterized by extremely early phenological development, and in most regions of Germany and Central Europe it goes through all the main phenophases significantly earlier than traditional varieties such as Riesling or Pinot Noir (Molitor et al., 2014). According to Stojanović et al., 2017, the Muscaris variety is known for its resistance to various climatic and phytopathological conditions. It has a specific phenological profile, characterized by moderately early budburst and flowering, which makes it suitable for regions with a continental climate (Petrović et al., 2019). The Hibernal variety has an early to medium early phenological development, suitable for cultivation in regions with a shorter growing season (Keller, M., 2015).

The study aims to track the phenological development and analyze the relationship between climatic factors and the dynamics of phenophases in the Solaris, Muscaris and Hibernal varieties to local climatic conditions in the Plovdiv region. The study contributes to establishing the varieties response to warmer climatic conditions and their adaptive capabilities, as they are grown in regions with continental climates. The phenological profile can serve as a basis for optimizing cultivation practices, and also as a basis for comparison when assessing the impact of climatic factors on other PIWI or traditional varieties for a given region.

MATERIALS AND METHODS

The study was conducted in the period 2024-2025, the vines were planted in the Training and Experimental and Implementation Base for Viticulture at the Agricultural University - Plovdiv, located in the land of the Kuklen town, on the border with the village of Brestnik, Rhodope Municipality. The study used three white wine varieties (Solaris, Muskaris and Hibernal), grafted on the rootstock Berlandieri x Riparia SO4, characterized by increased resistance to fungal diseases and low winter temperatures. The varieties were selected for regions with a cool climate and low levels of sunlight, one of the coldest wine regions in Europe.

Solaris

Solaris is a hybrid grown mainly in Baden, Germany, where it was developed in 1975 by Professor Helmut Becker. It was obtained by crossing the Merzling varieties (Seyve-villard 5276 x (Riesling x Pinot gris)) and the functionally named Gm 6493 – a cross between Zarya Severa × Muscat Ottonel. The name Solaris means “sun”, which is particularly appropriate, as the variety used in regions known for their cool climate and low levels of sunshine. In the coldest wine regions of Europe – Denmark, Norway and Sweden – Solaris has proven to be an invaluable wine grape variety. An early ripening variety with good resistance to fungal diseases, mainly downy mildew and medium resistance to powdery mildew and gray rot, as well as good resistance to low temperatures. In phenological terms, the bud burst, flowering and ripening phases occur quickly and intensively, compared to other varieties. The bunch is medium, almost wingless and medium density. The berries are small to medium sized, yellow-green in color with an oval shape.

The wines have fruity aromas, with notes of citrus fruits, banana, hazelnut and elderberry with high acidity. Suitable for production of sweet wines.

Muscaris

Muscaris was obtained by crossing the Solaris and Gelber Muskateller varieties at the Institute of Viticulture and Enology in Freiburg, Germany by Norbert Becker. It is also known as FR 493-87. In phenological terms, the phases occur quickly, with early bud burst and medium ripening time. The tendency to millerandage is medium. Resistance to fungal diseases downy mildew and gray rot is high, while powdery mildew is medium. It has good cold resistance. The clusters are small to medium-sized, the berries are medium-sized, and the color is deep green and remains so, even with very high sugar content. It is characterized by a very strong musket aroma. White wines are from weak to very dense, they also feel floral aromas with a slightly smoky aftertaste. Due to the early accumulation of sugars, it is suitable for the production of sweet wines.

Hibernal

Hibernal also known as GM 322-58, is a complex cross between the varieties Seibel 7053 (Chancellor x Riesling) and Seibel 7053 x Riesling. It contains genes from Vitis labrusca, Vitis lincecumii, Vitis rupestris and Vitis vinifera. The crosses were made in 1944 by Heinrich Birk Heinrich at the Institute of Viticulture and Enology Geisenheim, Germany. It was officially recognized as a variety in 1977. Distributed mainly in the cooler regions of Germany, Poland, the

Czech Republic, the USA and Canada. In phenological terms, the variety is medium to late ripening, resistant to low temperatures. Its resistance to fungal diseases is high. The bunch is small to medium-sized, compact, the berries are small, often deformed due to the compactness of the bunch. The skin color is green with a pink tint.

The wines are of excellent quality, with distinct aromas of lime blossom or peach, spicy notes, and a crusty texture. The wine flavors show hints of citrus fruits, green apple, and tropical fruits.

The vineyard is fruitful, it was established in 2023, the planting distance is 2.90 m between rows and 1.00 m between vines in the row - 3330 pcs/ha. The training system is a stem head, with a height of 50 cm. The loading was carried out by spur pruning with two buds. The rows are grassed, the soil surface between the vines is kept clean by applying herbicides. The vines are grown under non-irrigated conditions. The average altitude is 194 m. Phenological observations were conducted during the period 2024 and 2025. Normally developed vines were selected for this purpose. The beginning of the phase is considered the day on which 5% of the vines have entered it, mass entry - 50%, and the end when 95% of the vines have entered the respective phase.

The duration of the main phenophases in days is presented: bud burst, bud burst-beginning of flowering, flowering, end of flowering-beginning of vearison, veraiso, end of veraison-technological ripeness and bud burst-technological ripeness. The indicators were monitored according to the generally accepted methods described in the Manual for Exercises in Viticulture (Roychev et al., 2004).

The following climatic indicators were recorded: average air temperature, average relative air humidity and precipitation. The total and active temperature sum for the onset of the main phases and the entire growing period was determined. Soil parameters include soil moisture at a depth of 50 cm and soil temperature at a depth of 20 cm. The data on the climatic indicators for the study period were taken from the meteo station located in the Department of Viticulture.

RESULTS AND DISCUSSION

Earlier and faster warming occurs in 2024 (Table 1). The average temperatures in April/May are above 16°C, in the summer months (June, July, August) respectively 26–28°C, with maximum above 34–36°C. Summer is warm and hot. The early warming shows that the calendar phenological phases begin earlier, bud burst in early March. Summer is hot with high maximum temperatures, low precipitation with risks of water stress. Spring of 2025 is colder. In February, the average temperature is 1.7°C, and the minimum 3.3°C. There is a small difference in the minimum temperatures during the summer period: in 2025, the average for July is 18.1°C, and in 2024 it is 18.9°C. The amount of precipitation in 2025 is greater than in 2024, but in both years they are unevenly distributed throughout the growing season. The spring of 2025 is wetter in March and May, and the summer is drier, compared to 2024.

Table 1. Average monthly air temperature and precipitation amount January – September 2024 - 2025

Year	Temperature	Months									Total rain mm/m2
		I	II	III	IV	V	VI	VII	VIII	IX	
2024	Average-t ºC	3,6	9,8	10,4	16,1	16,5	26,1	28,1	26,7	21,1	294
	Max - t ºC	9,4	16,3	16,4	24,2	26,1	34,9	36,7	35,7	26,5	
	Min - t ºC	-1,8	3,1	5,0	8,5	10,8	16,9	18,9	17,8	17,7	
	Rain	49.6	6.8	53.4	37.2	82.2	4.8	21.6	20.2	18.2	
2025	Average - t ºC	3,4	1,7	10,5	11,9	17,2	24,7	27,7	24,5	21,2	347.6
	Max - t ºC	10,9	7,5	18,1	18,8	23,8	33,8	36,8	33,3	29,3	
	Min - t ºC	-1,7	-3,3	3,4	5,3	10,6	14,9	18,1	15,6	13,1	
	Rain	21	19.8	86.8	67.4	109.6	8.2	15.8	12	7	

Calendar time of onset and course of phenological phases:

SAP (Table 2): Due to the cooler spring of 2025, sap in all varieties begins quite late, in the last ten days of March. The growing season is pushed back by 22 to 25 days compared to the previous year.

Bud burst phase (Table 2): It begins 22 - 27 days earlier than in 2025. This is due to the higher average daily temperatures in February. In 2024, Solaris begins bud burst on 06.03, and Muskaris and Hibernal on 08.03. In the spring of 2025, bud burst is pulled out at the end of March for Solaris and the beginning of April for Muskaris and Hibernal. The duration of the phase, depending on the year, is 8-10 days.

Table 2. Beginning of SAP flow to a shoot with a 10-15 cm length, 2024 and 2025

Variety	Year	SAP		Bud burst			1st leaf	1st infloresc ens	Shoot 10-15cm
		start	mass	start	mass	end			
Solaris	2024	1.03	4.03	6.03	10.03	12.03	15.03	23.03	26.03
	2025	23.03	26.03	29.03	05.04	10.04	14.04	20.04	26.04
Muskaris	2024	29.02	4.03	8.03	11.03	14.03	18.03	25.03	28.03
	2025	24.03	27.03	01.04	06.04	09.04	18.04	23.04	27.04
Hibernal	2024	29.02	04.03	8.03	10.03	14.03	20.03	27.03	02.04
	2025	26.03	29.03	03.04	09.04	13.04	22.04	28.04	30.04

Appearance of the first leaf and first inflorescens (Table 2): The phase begins in Solaris on March 15, on March 18 for Muskaris and on March 20 for Hibernal. The following year, the sequence is maintained, but the period is delayed by one month due to the cool spring. Appearance of the first inflorescens in all three varieties occurs 6 to 7 days after the previous

phase in the same sequence Solaris, Muskaris and Hibernal. Three to five days after the appearance of the first inflorescens, the shoots reach a length of 10-15 cm.

Flowering (Table 3): The beginning of flowering in Solaris during 2024 begins on April 30, followed by Muskaris on June 6, and Hibernal on June 7. Mass flowering is in the same sequence 7-8 days later. The stage ends on 16.05 for Solaris and 22.05 for Muskaris and Hibernal. In 2025, flowering begins and proceeds in the same sequence Solaris, Muskaris, Hibernal in the period 19.05-05.06.

Veraison (Table 3): In 2024 begins early for Solaris (14.07), followed by Muskaris (15.07) and Hibernal (19.07). Mass veraison begins 7 to 9 days from the beginning in the same sequence. The process ends on 26.07 for Muskaris, 27.07 for Solaris and 07.08 for Hibernal. In 2025, it begins and proceeds in the same sequence in the period 20.07-07.08.

Technological ripeness (Table 3): In 2024 occurred earliest in Muskaris (04.08), followed by Solaris (05.08) and Hibernal (12.08). In 2025, technological ripeness occurs first in Solaris and Muskaris varieties on 12.08, and in Hibernal variety on 19.08.

Table 3. Beginning of flowering to technological ripeness, 2024 – 2025

Variety	Year	Flowering			"Pea" size	Veraison			Ripeness
		start	mass	end		start	mass	end	
Solaris	**2024**	30.04	8.05	16.05	14.06	14.07	20.08	27.08	5.08
	2025	19.05	22.05	30.05	13.06	20.07	25.07	03.08	12.08
Muskaris	**2024**	06.05	13.05	22.05	18.06	15.07	24.07	26.07	04.08
	2025	22.05	26.05	2.06	17.06	23.7	28.07	03.08	12.08
Hibernal	**2024**	07.05	14.05	22.05	26.06	19.07	26.08	04.08	14.08
	2025	26.05	01.06	05.06	19.06	23.07	01.08	7.08	19.08

The duration of the period for 2025 from beginning of bud burst to beginning of flowering for Solaris and Muskaris is 51 days and 53 days for Hibernal (Table 4). In 2024 the period is longer by 4 days for Solaris, 8 days for Muskaris and 7 days for Hibernal.

Table 4. Beginning of bud burst to beginning of flowering and related indicators.

Variety	Year	Period, days	Avg. daily temp *t°C*	Relative air humidity %	Soil moisture at 50 cm deep %	Soil temp. at 20 cm deep, *t°C*	Rain, mm	Total temperature sum *∑t°C*	Active temperature sum, *∑t° C*
Solaris	**2024**	55	13,6	67,7	90,1	13,7	66,8	750,1	341,1
	2025	51	13,4	75,7	94,7	14,3	199,4	683	253
	Avg.	**53**	**13,5**	**71,7**	**92,4**	**14**	**133.1**	**716.55**	**297,05**
Muskaris	**2024**	59	13,9	68,2	88,7	14,1	103,8	808,0	338
	2025	51	13,8	73,6	94,7	14,6	135	703	273
	Avg.	**55**	**13,85**	**70,9**	**91,7**	**14,35**	**119.4**	**755.5**	**305,5**
Hibernal	**2024**	60	14,1	68,2	88,6	14,1	103,8	860,2	380,2
	2025	53	14,3	73,1	94,5	15,1	133,4	756,7	298,7
	Avg.	**56,5**	**14,2**	**70,65**	**91,55**	**14,6**	**118.6**	**808.45**	**339,45**

During the study, period passes at the same average daily air temperature, on average for Solaris - 13.5ºC, Muskaris 13.85ºC and 14.2 ºC for Hibernal. The accumulated active temperature sum for this period is on average 297.05ºC for

Solaris, for Muskaris - 305.5ºC and Hibernal - 339.45ºC. The shortening of the period from bud burst to flowering by 4 to 8 days in 2025 is due to the higher soil moisture ((Solaris-94.1%, Muskaris-94.7% and 94.5% for Hibernal) and the higher average soil temperature at a depth of 20 cm (Solaris-14.3ºC Muskaris-14.6º C and 15.1ºC for Hibernal), compared to the values in 2024 of soil moisture at a depth of 50 cm (Solaris-90.1%, Muskaris-88.7% and 88.6% for Hibernal) and soil temperature at a depth of 20 cm (Solaris-13.7ºC, Muskaris-14.1º C and 14.1ºC for Hibernal). The simultaneous increase in the values of these indicators leads to a moderate acceleration of development of the vines in the early stages of vegetation, which is the reason for shortening the period.

The duration from beginning to the end of flowering in 2025 for Solaris and Muskaris varieties is 12 days and 11 days for Hibernal. In 2024, the period is longer by 5 days. The transition of the phase occurs at an average daily air temperature for Solaris-16.85ºC, Muskaris-17.3ºC and 18.15ºC for Hibernal, and the sum of the active temperature is 103.3ºC for Solaris, 93.4ºC for Muskaris and 103.95ºC for Hibernal. The longer flowering duration by 5 days in 2024 is due to the lower average air temperature in this period (15.1ºC-Solaris, Muskaris - 15.7ºC and Hibernal-15.6ºC), compared to the average temperature for 2025 (18.6ºC-Solaris, Muskaris-18.9ºC and Hibernal-20.7 ºC).

Table 5. Beginning to the end of flowering and related indicators

Variety	**Year**	**Period, days**	**Avg. daily temp *tºC***	**Relative air humidity %**	**Soil moisture at 50 cm deep %**	**Soil temp. at 20 cm deep, *tºC***	**Rain, mm**	**Total temperature sum ∑*tºC***	**Active temperature sum, ∑*tº C***
Solaris	**2024**	17	15,1	80,3	88,9	16,1	76	256,7	86.7
	2025	12	18,6	68,1	95	18,3	1,4	239,9	119.9
	Avg.	**14,5**	**16,85**	**74,2**	**91,95**	**17,2**	**38.7**	**248.3**	**103.3**
Muskaris	**2024**	17	15,7	82,1	96,4	16,5	48	249,1	79.1
	2025	12	18,9	69,3	94,6	18,9	25,2	227,7	107.7
	Avg.	**14,5**	**17,3**	**75,7**	**95,5**	**17,7**	**36.6**	**238.4**	**93.4**
Hibernal	**2024**	16	15,6	82,6	96,8	16,5	48	90.1	170,1
	2025	11	20,7	65,8	94,4	20,3	6,4	227,8	117.8
	Avg.	**13,5**	**18,15**	**74,2**	**95,6**	**18,6**	**27.2**	**238.55**	**103.95**

Lower soil temperature in 2024 at a depth of 20 cm was also recorded (16.1ºC - Solaris, Muskaris-16.5ºC and Hibernal-16.5ºC), compared to 2025 (18.3º - Solaris, Muskaris-18.9ºC and Hibernal-20.3ºC). The low values of these indicators in 2024 are due to the higher amount of precipitation that fell during flowering (Solaris-76mm, Muskaris-48mm and Hibernal-48mm).

From the end of flowering to beginning of veraison in 2025 for Solaris and Muskaris, 50 days are required, while for Hibernal - 47 days. In 2024 the interval is longer by 8 days for Solaris, by 3 days for Muskaris and 10 days for Hibernal (Table 6). The average air temperature for Solaris is 24.85ºC, for Muskaris -

25.75ºC and for Hibernal - 26ºC. The accumulated active temperature sum for this time interval is on average - 804.8ºC for Solaris, for Muskaris - 823.7ºC and for Hibernal - 829.2ºC. The accumulation of a larger active temperature sum is due to the lower soil moisture at a depth of 50 cm in 2024 (71.5%-Solaris, Muskaris-68.1% and Hibernal-67.1%) compared to 2025 (85.1%-Solaris, Muskaris-83.6% and Hibernal-82.9%), which in combination with high temperature causes moderate water stress (vines temporarily slow down their physiological processes), which delays plant development and extends the duration of the phases.

Table 6. End of flowering to beginning of veraison and related indicators

Variety	Year	Period, days	Avg. daily temp *tºC*	Relative air humidity %	Soil moisture at 50 cm deep %	Soil temp. at 20 cm deep, *tºC*	Rain, mm	Total temperature sum $\sum$ *tºC*	Active temperature sum, $\sum t^o C$
Solaris	**2024**	58	24,4	60,8	71,5	26,3	29,4	1414,2	834.2
	2025	50	25,5	57,3	85,1	27,2	11,6	1275,4	775.4
	Avg.	**54**	**24,85**	**59,05**	**78,3**	**26,75**	**20.5**	**1344.5**	**804.8**
Muskaris	**2024**	53	25,4	57,8	68,1	27,5	15,4	1374,6	844.6
	2025	50	26,1	56,1	83,6	27,7	11,2	1302,8	802.8
	Avg.	**51,5**	**25,75**	**56,95**	**75,85**	**27,6**	**13.3**	**1338.7**	**823.7**
Hibernal	**2024**	57	25,8	56,2	67,1	27,9	16	1468,8	898.8
	2025	47	26,2	55,4	82,9	28	11,2	1229,6	759.6
	Avg.	**52**	**26**	**55,8**	**75**	**27,95**	**13.6**	**1349.2**	**829.2**

Similar results for delay of phenophases at lower soil moisture were reported by Falcão et al., (2021), according to which moderate water deficit can lead to slow cell growth and phase extension. Some studies (Vannozzi et al., 2023) suggest that under moderate deficit the vine develops adaptation mechanisms that can partially compensate for the effect on phenology. According to the same authors, lower soil moisture can affect the hormonal balance in the plant (increase in abscisic acid) and delay the transition between phases. Sensitivity to water stress varies between individual varieties. Muskaris shows greater tolerance to low soil moisture content in 2024 - 68.1%, compared to 2025 - 83.6%, In this case, the extension of the period is three days, with a difference in the active temperature sum between the two years of 41.8ºC. New studies based on genomic expression have shown that resistant varieties activate specific genes related to the response to water stress, including those that regulate the production of abscisic acid and antioxidants (Vannozzi et al., 2023).

From beginning to the end of veraison, the duration for Muskaris in both years was 12 days, in Solaris it was an average of 14.5 days, in Hibernal -16.5 days (Table 7). No significant differences in the phase duration were noted in the years studied. It occurred at relatively similar average daily air temperatures in the individual varieties.

Table 7. Start to finish of veraison and related indicators

Variety	Year	Period, days	Avg. daily temp t^oC	Relative air humidity %	Soil moisture at 50 cm deep %	Soil temp. at 20 cm deep, t^oC	Rain, mm	Total temperature sum $\sum t^oC$	Active temperature sum, $\sum t^o C$
Solaris	**2024**	9	28,6	51,8	55,5	30,7	11,6	400	260
	2025	9	28,1	56,3	69,4	30,6	12,8	421	271
	Avg.	**9**	**28,55**	**54,05**	**62,45**	**30,65**	**12.2**	**410.5**	**265.5**
Muskaris	**2024**	9	28,5	53,5	55,3	30,7	11,6	341,9	221.9
	2025	9	27,8	57,7	68,9	30,8	12,8	334	214
	Avg.	**9**	**28,15**	**55,6**	**62,1**	**30,75**	**12.2**	**337.95**	**217.95**
Hibernal	**2024**	10	27,5	50,7	57,7	29,4	11,8	467,5	297
	2025	12	27,4	57,6	68,5	30,1	14	438,5	278.5
	Avg.	**11**	**27,45**	**54,15**	**63,1**	**29,75**	**12.9**	**453**	**287.75**

The accumulation of active temperature sum for the period averages 265.5ºC for Solaris, 217.95ºC for Muskaris and 287.75ºC for Hibernal. A difference is noted in soil moisture at a depth of 50 cm, as in 2025 it is 69.4%, compared to 2024 – 50.7%. Despite the lower soil moisture in 2024, the phase passes at approximately same active temperature sum and duration in the two years of the study. This is noted for the three varieties and shows that they have phenological stability, do not change the duration of the phase significantly under moderate water stress.

From end of veraison to the onset of technological ripeness, the average daily temperature for Solaris is 27.25ºC, for Muskaris - 27.3ºC and 26.5ºC for Hibernal (Table 8). The accumulated active temperature is 154.95ºC for Solaris, 168.75ºC for Muskaris and 179.95ºC for Hibernal. The stage duration for Solaris and Muskaris is 9 days, while for Hibernal in 2024 it is 10 days, and in 2025 it is 12 days. The period increase in 2025 is by two days for the Hibernal variety and is due to the lower average air temperature (25.4 ºC) and lower soil temperature - 27.7ºC, compared to 2024 - average air temperature - 27.6ºC and soil temperature - 29.06º C. The total duration of the period from bud burst to technological ripeness is 142 days for Muskaris, 145 days for Solaris and 149.5 days for Hibernal (Table 9). There are differences in the duration in 2024, which is 16 days longer for Muskaris and Solaris, and 21 days for Hibernal. These differences are mainly due to the amount of precipitation that provides soil moisture.

The smallest sum of active temperature from beginning of bud burst to technological ripeness is observed in Muskaris - 1609.3ºC, with a total temperature sum of 2931.45ºC, followed by Solaris with an active temperature sum of 1625.6ºC. The Hibernal has the largest sum of active temperature for this period - 1780.3ºC.

Table 8. End of veraison till technological ripeness and related indicators

Variety	Year	Period, days	Avg. daily temp *tºC*	Relative air humidity %	Soil moisture at 50 cm deep %	Soil temp. at 20 cm deep, *tºC*	Rain, mm	Total temperature sum ∑*tºC*	Active temperature sum, ∑*tº C*
Solaris	**2024**	9	27,6	43	59,1	29,3	0,2	248	158
	2025	9	26,9	55,5	66,8	28,2	1,4	241,9	151.9
	Avg.	**9**	**27,5**	**49,25**	**62,95**	**28,75**	**0.8**	**244.95**	**154.95**
Muskaris	**2024**	9	27,7	42,5	59,1	29,1	0,2	249,5	159.5
	2025	9	26,9	55,5	66,8	28,2	1,4	268	178
	Avg.	**9**	**27,3**	**49**	**62,45**	**28,65**	**0.8**	**258.75**	**168.75**
Hibernal	**2024**	10	27,6	47,2	59,2	29,6	3,4	275,5	175
	2025	12	25,4	57,7	66,4	27,7	8,6	304,9	184.9
	Avg.	**11**	**26,5**	**52,45**	**62,8**	**28,65**	**6.0**	**290.2**	**179.95**

Table 9. Period from bud burst to technological ripeness and accumulated temperature sum.

Variety	Year	Period, days	Total temperature sum, ∑tºC	Active temperature sum, ∑tº C
Solaris	**2024**	153	3069,6	1680
	2025	137	2844	1571,2
	Avg.	**145**	**2956.8**	**1625,6**
Muskaris	**2024**	150	3053,5	1643,1
	2025	134	2809,4	1575,5
	Avg.	**142**	**2931.45**	**1609,3**
Hibarnal	**2024**	160	3302,3	1921,1
	2025	139	2957	1639,5
	Avg.	**149,5**	**3129.65**	**1780,3**

CONCLUSIONS

A similarity is observed in the dynamics of development of phenological phases. From bud burst to technological ripeness, white wine varieties Solaris, Muskaris and Hibernal react poorly differentiated to climatic changes within the period under consideration. The phases occur in close time frames. This emphasizes the high physiological stability of these varieties in a variable climate.

Temperature is a major factor determining the beginning, duration and completion of phenological phases. The moisture regime has a more limited influence on the duration, but in years with a pronounced deficit it causes water stress and can have a stronger impact.

The duration of the period from bud burst to technological ripeness is between 134 and 160 days. Technological ripeness occurs by August 20, which reduces the risk of autumn climatic anomalies unfavorable for grapes quality. The active temperature sum required to reach technological ripeness is in the range between 1571.2°C and 1921.1°C. These varieties have low heat requirements and good adaptation to various climatic conditions.

The results obtained have practical significance in the selection of varieties according to production goals, planning agrotechnical measures depending on climatic resources and assessing the risk of climatic anomalies such as late spring frosts or drought

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