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Influence of Varietal Variety and Climatic Year on the Phenology of Some Table Grape Varieties Grown in the Murfatlar Area, Romania

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Abstract: This study aimed to assess the influence of recent climatic conditions and cultivar on the timing of key phenological stages in grapevines. For this purpose, five table grape varieties with different ripening periods, grown at the Murfatlar viticultural center and vineyard in Romania, were studied. This vineyard is challenged by current climatic changes. At the local level, data have been recorded showing constant climatic changes, with changing temperature and humidity regimes. These data will lead to management problems that other vineyards are already facing. The study covered the period from 2000 to 2019 and tracked the timing of the onset of vegetative phases, as recorded in the number of days from January 1 to that point, according to the BBCH phenological scale. The results showed that the length of the vegetation period depends not only on the variety but also on the viticultural year, due to annual climatic variability. Changes in the duration of the vegetative phases were evidenced, with a trend towards advancing ripening.

Keywords: phenology; climate change; grape table

1. Introduction

Romanian viticulture is recognized for the diversity of varieties used to produce high-quality wines, including white, red, and aromatic varieties [1]. It is also notable for the production of table grapes, with the wine sector experiencing steady development following the country's accession to the European Union in 2007 [2].

Cultivation and quality of grapes depends on several key factors of the terroir concept (soil, climate, slope and exposure, etc.) but to a large extent on the stability and favorability of climatic parameters of the growing area: heat balance, actual insolation, number of possible growing days, annual minimum and maximum temperatures, water balance during growing and resting periods, precipitation during resting and growing periods, number of useful rainfalls (>10 mm) and relative humidity. Some values of environmental factors may be restrictive for grapevine phenology, including minimum air temperatures (< -150 °C), extreme temperatures during the growing season, drought [3], late spring and early fall frosts, and high wind frequency [4].

Viticultural regions and vineyards alike exhibit variability in both phenology and terroir, representing interesting material for current scientific research in the context of changing climatic factors [5].

Climatic factors play a crucial role in determining the timing of the main phenological stages. Vines have been shown to respond to a warming climate by advancing the main phenological stages and shortening the phenological interval. At the scale of viticultural regions, climate and, in

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particular, humidity are key terroir factors that dictate grape quality. At the vineyard level, where the climate is more consistent, soil composition also contributes to the final quality of the grapes [5]. Temperature, is the limiting parameter for grapevine cultivation because the vineyard area, cropping system, phenophase onset and progression, production quantity and quality are decisively determined by it, requiring continuous evaluation by calculating specific parameters: overall heat balance (Σtºg), active heat balance (Σtºa) and useful heat balance (Σtºu) [6,7]. The ripening of table grapes requires cycles of cooler temperatures with high diurnal fluctuations [8]. In recent decades, due to climate change, grape ripening has occurred under warmer and drier conditions, resulting in reduced grape yield and quality [9,10]. The observed trend is an increase in evapotranspiration, the direct consequence of which is the application of irrigation [11]. As a result of climate change, the increase in temperature associated with variable rainfall can lead to mild to severe stress, reducing yield and improving grape quality [11,12].

Although this problem has been addressed through technological improvements, recent changes in temperature, as well as sunshine duration and rainfall, reveal a concerning trend for grapevine cultivation [13]. Therefore, understanding the thermal requirements and thresholds for viticulture is crucial not only for sustaining traditional wine-growing regions but also for identifying new cultivation opportunities in the context of global warming [14,15]. Another determining parameter for vine phenology is light, with the light resources of a vineyard assessed in terms of the sum of hours of effective sunshine during the growing season (actual insolation), which in our country's conditions ranges from 1200 to 1600 h [16]. Humidity can be a restrictive factor for grapevines under prolonged drought conditions. However, the grapevine is a plant with the potential to adapt due to its well-developed root system to both drought and high humidity conditions [17]. Climate change adaptation strategies are crucial in viticulture, as it is a dynamic socio-economic activity in most regions of the world, with short-term strategies being widely employed despite growing concerns about their sustainability [18,19]. To better understand the traits underlying the adaptive capacity of grapevine to current climate change, the integration of research in plant physiology, biochemistry, histology and genetics is needed [20]. Studies on how climate change might modify the risk of plant frost have shown that it remains low for viticulture [21].

Several traits, including morphological, physiological and molecular aspects, are essential for adaptation to environmental stresses such as drought and heat. By studying the abundant intervarietal diversity of grapevines, the potential for adapting viticulture to climate change through varietal selection is immense [20]. Although the plant response to light and heat stress is well understood, as grapevine varieties exhibit different molecular mechanisms of leaf cell homeostasis, the ability to develop heat stress tolerance strategies requires further investigation. This is because morpho-anatomical and physiological traits may vary depending on the intensity and duration of stress, as well as the genotype × environment combination [22]. Additionally, by combining genomic and environmental data, breeders can more accurately predict varietal performance, thereby enhancing breeding efficiency and facilitating the development of high-quality grapevine cultivars [23]. Variations in planting sites, particularly between lowland and mountainous areas, also affect temperature and climatic conditions [24]. Variation in phenological responses of table grape varieties due to temperature differences requires future genotype management and active management applied at the vineyard level [25,26].

Mediterranean countries are expected to face substantial increases in temperature, prolonged periods of severe drought, increased levels of ultraviolet (UV) radiation and a higher frequency of extreme weather events [20,27–29]. Europe is emerging as a particularly climatically sensitive area, where the grapevine is recognized as one of the most important crops. There is growing evidence of the significant impact of climate change on the timing of grapevine phenological stages, which necessitates the scientific community's investigation into the potential evolution of this impact in the coming decades [29,30]. Climate projections for the near future (2020-2060) indicate a delay of budburst by 7 to 8 days and of ripening by 4 to 5 days on average. For the far future (2060-2100), the respective changes are 11 to 18 and 7 to 9 days earlier [30]. Studies [31,32] suggest that phenological models based on the growing degree days (GDD) index could be useful planning tools for viticulture, especially from vegetative initiation to flowering for table grape varieties.

In the current climatic context, the phenophase of table grapes may change. For this reason, further local and regional studies are needed to assess the climatic impact on the progression of vegetation phases and to contribute to the implementation of effective strategies in response to climate change [33,34]. This is also the aim of the current study, which proposes to evaluate the influence of climatic year and varietal characteristics on the development of vegetative phases in table grape varieties grown in Murfatlar, Romania.

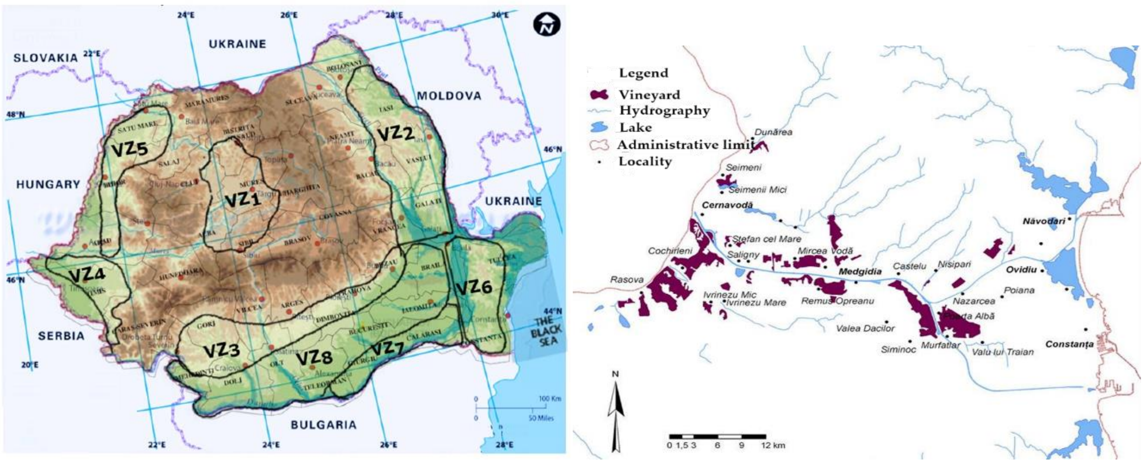
2. Materials and Methods

Location. The study was conducted in Podgoria, specifically in Murfatlar, at the Murfatlar viticultural center. The vineyard is situated in the central part of the Dobrogea shelf, along the linear slopes of the Danube-Black Sea Canal, extending from Poarta Albă-Nazarcea to Cernavodă, then south to Cochirleni and Rasova, and north to Seimenii Mici, within the Dobrogea Hills Wine Region (Figure 1a, VZ 6). The geographical coordinates are 44°11′ north latitude and 28°23′ east longitude, relative to the equator and the Greenwich meridian. The Murfatlar vineyard comprises three vineyard centers situated at varying altitudes: Murfatlar (57 m), Medgidia (60 m), and Cernavoda (75 m) (Figure 1b). The *Murfatlar wine-growing center* is situated in the central-southeastern part of Constanța County, characterized by predominantly chernozemic or kastanozemic soils with a loamy texture, high edaphic volume, and good overall drainage. At the soil level, humus ranges from 2.5% to 3%, nitrogen from 0.16% to 0.22%, and total phosphorus from 0.07% to 0.11%.

Climatic conditions. During the period of the phenological study (2000-2019), the mean annual temperature was 14.42°C, the actual insolation during the growing season was 1675.7 h, and the annual precipitation volume was 503.3 l/m², of which 303.9 l/m² occurred during the growing season.

Plant material. The table grape varieties studied in this research are five in number and differ in ripening time: early (Victoria, Cardinal), medium (Muscat de Hamburg), and late (Italia, Afuz-Ali). Planting distances are 2,2 m between rows and 1,4 m between plants per row. Row orientation is N-S. The pruning system used is Dr. Jules Guyot.

Phenological data. The phenological observations were carried out from the beginning of vegetation to maturity.



a) b)

Figure 1. a). Viticultural zones in Romania [35]; b). Map of the Murfatlar vineyard [36].

Four main phenophases were followed, according to the BBCH (Federal Institute of Biology and Chemical Industry) monograph: BBCH 09 (Bud burst), BBCH 61 (Beginning of flowering), BBCH 81 (Beginning of ripening), BBCH 89 (Full maturity). Thirty observations were made for each variety,

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with the results expressed as an average. Phenophases were recorded as several days since January 1 (day of year, DOY).

Statistical analysis. Each data set was statistically analyzed using JASP 0.19.3.0. program for descriptive analysis and correlations.

3. Results and Discussion

The progress through the vegetative phases of the varieties is influenced by both climate and biological characteristics of each variety. The descriptive statistical analysis of the influence of variety on phenophases in table grape varieties grown in the Murfatlar wine-growing center is presented in Table 1. It can be observed that all phenophases start earlier in the varieties Cardinal and Victoria, followed by Muscat de Hamburg, then Afuz-Ali and Italia. This is also their ripening order. It is observed that the onset of each vegetative phase occurs earlier for varieties with shorter vegetation periods and later for those with longer vegetation periods. During this period, at Murfatlar, the Cardinal variety required, on average, 239.2 days to ripen, Victoria 253.4 days, Muscat de Hamburg 261.2 days, Afuz-Ali 272.9 days and Italia 275.4 days. The vegetation period characterizes each variety and is also evident in varieties grown for wine [37]. If we consider each phenophase, the number of days from January 1 to onset varied for the same variety during the analyzed period. The BBCH 09 stage unfolded most clustered, with the amplitude of varieties ranging from 4 to 10 days. This phenotype showed the lowest amplitude. The data are in agreement with those previously reported, which indicate that the variability of this phenophase is low [38]. In this context, the maximum amplitude was recorded in the Afuz-Ali variety, which maintained this characteristic in both the BBCH 61 and BBCH 81 phenophases.

Table 1. Descriptive statistics on the influence of variety on phenotypes of table grape varieties grown in Murfatlar (2000-2019).

Phenophase	Variety	Mean	SD	CV (%)	Shapiro–Wilk	p-Value of Shapiro–Wilk	Minimum	Maximum
BBCH 09 (Bud burst)	Victoria	108.750	1.997	1.836	0.944	0.284	106.000	113.000
	Cardinal	109.500	1.573	1.437	0.942	0.265	107.000	113.000
	Muscat Hamburg	110.100	1.021	0.927	0.790	< 0.001	109.000	113.000
	Italia	113.650	1.461	1.286	0.889	0.026	110.000	117.000
	Afuz-Ali	111.750	2.359	2.111	0.754	< 0.001	109.000	119.000
BBCH 61 (Beginning of flowering)	Victoria	148.600	1.789	1.204	0.937	0.212	145.000	151.000
	Cardinal	149.300	3.230	2.163	0.953	0.410	144.000	155.000
	Muscat Hamburg	152.200	3.443	2.262	0.920	0.098	148.000	160.000
	Italia	153.150	4.320	2.821	0.951	0.380	147.000	161.000
	Afuz-Ali	153.850	4.295	2.792	0.929	0.147	146.000	160.000
BBCH 81 (Beginning of ripening)	Victoria	198.000	1.124	0.568	0.907	0.056	196.000	200.000
	Cardinal	198.100	1.294	0.653	0.917	0.088	195.000	200.000
	Muscat Hamburg	230.100	1.651	0.718	0.889	0.026	226.000	232.000
	Italia	233.650	2.870	1.228	0.870	0.012	229.000	241.000
	Afuz-Ali	232.600	3.619	1.556	0.962	0.581	226.000	242.000
BBCH 89 (Full maturity)	Victoria	253.450	4.395	1.734	0.895	0.033	245.000	259.000
	Cardinal	239.250	7.779	3.251	0.941	0.250	227.000	251.000
	Muscat Hamburg	261.200	5.053	1.935	0.814	0.001	245.000	269.000
	Italia	275.450	3.620	1.314	0.894	0.032	271.000	283.000
	Afuz-Ali	272.900	4.315	1.581	0.876	0.015	268.000	281.000

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SD = standard deviation; CV = coefficient of variation.

During the 3 phenophases, Victoria evolved more clustered, with a maximum amplitude of 7 days. The last phenophase (BBCH 89) is characterized by the highest amplitude, which, depending on the variety, ranges from 12 to 24 days. Italia recorded the highest amplitude at BBCH 61, Afuz-Ali at BBCH 81 and Victoria, Muscat de Hamburg and Cardinal at BBCH 89.

The shortest interphase interval was between BBCH 09 and BBCH 61. Varieties were clustered in this respect, ranging between 37 and 39 days. The longest interval was between BBCH 61 and BBCH 81, ranging from 51 to 82 days. Low values characterized the early-maturing varieties, and the highest values were recorded by the late-maturing varieties. The standard deviation and coefficient of variation have low values, indicating homogeneity among the analyzed varieties. The distribution of statistically analyzed data is normal, with two exceptions: phenotype BBCH 09, Afuz-Ali, and Muscat Hamburg (Shapiro-Wilk p-value < 0.001).

The descriptive statistical analysis of the influence of the year on the phenotypes of table grape varieties grown in the Murfatlar viticultural center is presented in Table 2. The distribution of statistically analyzed data is normal. For the first phases of vegetation, the standard deviation and the coefficient of variation indicate a distribution clustered around the mean of the values; as a result, there is good uniformity in the onset of vegetation and the beginning of flowering.

Table 2. Descriptive statistics on the influence of the year on phenotypes of table grape varieties grown in Murfatlar (2000-2019).

Phenophase	Year	Mean	SD*	CV (%)	Shapiro–Wilk	p-Value of Shapiro–Wilk	Minimum	Maximum
BBCH 09 (Bud burst)	2000	110.800	2.280	2.058	0.961	0.814	108.000	114.000
	2001	111.200	2.280	2.050	0.961	0.814	108.000	114.000
	2002	111.200	1.643	1.478	0.779	0.054	110.000	114.000
	2003	112.600	3.782	3.359	0.786	0.062	110.000	119.000
	2004	112.800	1.095	0.971	0.828	0.135	111.000	114.000
	2005	111.800	3.114	2.785	0.885	0.332	108.000	115.000
	2006	111.600	2.881	2.582	0.871	0.269	109.000	116.000
	2007	110.000	3.240	2.945	0.922	0.543	106.000	115.000
	2008	111.800	2.950	2.639	0.688	0.007	110.000	117.000
	2009	111.200	1.643	1.478	0.779	0.054	110.000	114.000
	2010	110.200	2.775	2.518	0.939	0.656	107.000	114.000
	2011	110.400	1.673	1.515	0.881	0.314	109.000	113.000
	2012	112.000	1.225	1.094	0.833	0.146	111.000	114.000
	2013	110.400	1.673	1.515	0.881	0.314	109.000	113.000
	2014	109.800	2.387	2.174	0.974	0.899	107.000	113.000
	2015	110.200	2.490	2.260	0.895	0.384	108.000	114.000
	2016	110.600	2.702	2.443	0.903	0.427	108.000	115.000
	2017	109.000	2.000	1.835	0.905	0.440	106.000	111.000
	2018	108.800	2.683	2.466	0.916	0.502	106.000	113.000
	2019	108.600	1.517	1.397	0.803	0.086	107.000	110.000
BBCH 61 (Beginning of flowering)	2000	148.400	1.817	1.224	0.867	0.254	146.000	150.000
	2001	149.800	0.837	0.558	0.881	0.314	149.000	151.000
	2002	149.000	2.449	1.644	0.833	0.146	147.000	153.000
	2003	153.800	5.404	3.514	0.957	0.785	147.000	160.000
	2004	155.800	5.762	3.698	0.712	0.013	149.000	160.000
	2005	154.200	4.868	3.157	0.937	0.643	149.000	161.000
	2006	154.800	6.058	3.913	0.860	0.228	146.000	160.000
	2007	151.600	3.782	2.495	0.800	0.081	147.000	155.000

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	2008	153.800	1.924	1.251	0.979	0.928	151.000	156.000
	2009	152.400	3.912	2.567	0.902	0.421	147.000	156.000
	2010	150.200	3.899	2.596	0.908	0.455	145.000	154.000
	2011	150.000	3.162	2.108	0.912	0.482	147.000	155.000
	2012	152.000	3.082	2.028	0.903	0.429	149.000	156.000
	2013	151.600	2.881	1.900	0.951	0.742	148.000	155.000
	2014	151.800	4.764	3.138	0.711	0.012	149.000	160.000
	2015	151.600	3.286	2.168	0.845	0.179	149.000	157.000
	2016	149.600	4.159	2.780	0.947	0.715	145.000	155.000
	2017	149.400	3.847	2.575	0.829	0.137	146.000	154.000
	2018	151.400	2.408	1.590	0.957	0.787	148.000	154.000
	2019	147.200	2.168	1.473	0.871	0.272	144.000	149.000
BBCH 81 (Beginning of ripening)	2000	218.400	18.202	8.334	0.736	0.022	198.000	233.000
	2001	217.600	18.407	8.459	0.751	0.030	197.000	233.000
	2002	215.400	17.869	8.296	0.793	0.071	195.000	232.000
	2003	220.000	19.455	8.843	0.862	0.235	199.000	241.000
	2004	218.400	19.604	8.976	0.731	0.020	197.000	234.000
	2005	219.600	19.655	8.950	0.822	0.121	198.000	240.000
	2006	218.600	17.925	8.200	0.727	0.018	199.000	233.000
	2007	218.400	18.743	8.582	0.766	0.041	198.000	235.000
	2008	219.000	18.722	8.549	0.706	0.011	198.000	233.000
	2009	218.600	17.516	8.013	0.758	0.035	199.000	234.000
	2010	217.000	17.903	8.250	0.761	0.037	197.000	232.000
	2011	218.600	20.330	9.300	0.781	0.057	196.000	237.000
	2012	220.600	20.256	9.182	0.835	0.153	199.000	242.000
	2013	217.400	16.817	7.736	0.719	0.015	199.000	231.000
	2014	219.200	19.867	9.063	0.748	0.029	197.000	236.000
	2015	219.600	18.863	8.590	0.736	0.022	199.000	235.000
	2016	218.800	17.641	8.063	0.727	0.018	199.000	233.000
	2017	219.000	20.285	9.263	0.758	0.036	197.000	236.000
	2018	218.000	20.112	9.226	0.722	0.016	196.000	234.000
	2019	217.600	17.897	8.225	0.698	0.009	198.000	231.000
BBCH 89 (Full maturity)	2000	258.200	19.867	7.694	0.977	0.916	231.000	281.000
	2001	260.000	17.479	6.723	0.920	0.528	236.000	277.000
	2002	258.000	15.540	6.023	0.914	0.494	237.000	273.000
	2003	263.400	13.704	5.203	0.919	0.525	244.000	277.000
	2004	266.400	13.520	5.075	0.975	0.906	249.000	283.000
	2005	265.000	10.977	4.142	0.998	0.998	251.000	280.000
	2006	260.600	11.502	4.414	0.914	0.490	244.000	272.000
	2007	261.600	17.038	6.513	0.975	0.906	238.000	281.000
	2008	263.400	13.831	5.251	0.949	0.727	247.000	281.000
	2009	260.200	15.675	6.024	0.996	0.997	239.000	281.000
	2010	262.200	11.946	4.556	0.918	0.519	251.000	280.000
	2011	258.600	14.673	5.674	0.924	0.557	236.000	273.000
	2012	258.400	18.916	7.320	0.885	0.331	228.000	275.000
	2013	260.800	18.674	7.160	0.850	0.195	230.000	276.000
	2014	262.400	18.366	6.999	0.913	0.487	233.000	280.000
	2015	253.600	14.876	5.866	0.853	0.205	238.000	271.000
	2016	262.000	12.748	4.866	0.863	0.238	248.000	276.000
	2017	259.000	12.884	4.975	0.849	0.190	245.000	272.000
	2018	258.200	16.146	6.253	0.861	0.232	232.000	272.000

2019	257.000	18.166	7.068	0.873	0.280	227.000	273.000

*SD = standard deviation; CV = coefficient of variation.

Stage BBCH 09 was triggered after 108.6 - 112.8 days from January 1, and stage BBCH 61 after 147.2 - 155.8 days. The annual amplitude ranged from 3 to 9 days for BBCH 09 and from 2 to 14 days for BBCH 61. The BBCH 81 stage is characterized by higher values of the coefficient of variation and standard deviation, which indicate a phenophase with an average uniformity in terms of onset time. The amplitude is between 32 and 43 days, with the phenophase manifesting after 215.4 - 220.6 days from the onset. The last phenophase is comparable in terms of uniformity to the previous one and is triggered 253.6-266.4 days after the beginning of the year, characterized by an amplitude of 27-50 days.

The average distances between the four phenophases are 40.6, 67.0, and 41.9 days, respectively. The annual variations can be attributed to the variability of climatic conditions, particularly temperature, which is more closely linked to the onset of phenophases than humidity [39,40].

Recent studies have highlighted changes in the dynamics of vegetation phase unfolding in relation to temperature, which is of importance in the context of global warming [41]. Elevated temperatures correlate well with the timing of flowering, fruit set and ripening, in terms of the avulsion of these phenophases, with variations by vineyard and variety [42]. The greatest impact on phenophases was identified for average temperatures in March (for budbreak), May (for flowering) and August, in terms of ripening and harvest [43].

Similar observations on some wine grape varieties have shown that in recent years, we are witnessing an advancement of the vegetative phases, while the intervals between some phenophases are decreasing [43]. If we follow the dynamics of the number of days from January 1 to the recording of the ripening phase of the grapes (BBCH 89), we observe a decreasing trend over the 20-year study period. The separate analysis of each phenophase showed a more pronounced upward trend for the BBCH 09 stage compared to the BBCH 61 and BBCH 89 stages. Leek (BBCH 81) is the only stage that remains relatively unaffected, remaining approximately constant over the 2000-2019 period. The data obtained are confirmed by other studies, which show that the advancement of the harvest is explained by a reduction in the duration between phenophases [44]. The reduction in the vegetation cycle has also been reported for other species of the genus Vitis (e.g., Vitis labrusca L.), which, under the given climatic conditions, leads to two harvests per year [45]. Essentially, we are witnessing an advancement of the vegetative stages, which can be attributed to the warming climate. However, there are situations where an early bud burst cannot be correlated with advanced ripening if reduced temperatures occur during the growing season [46].

Pearson's coefficient was used to determine the correlation between the durations of the analyzed phenophases, and the results are presented in the form of a correlation matrix (Table 3). The correlation coefficients had positive values and are statistically assured. The table shows that all the phenophases correlate with each other, indicating that the number of days until the onset of one phenophase influences the duration of subsequent phenophases. It can be observed that the analyzed phenophases correlate with each other positively distinctly significantly without exception. Pearson's coefficient values ranged between 0.445 and 0.828.

Table 3. Matrix of correlations between analyzed phenotypes of table grape varieties grown in Murfatlar (2000-2019).

Variable		BBCH 09	BBCH 61	BBCH 81	BBCH 89
BBCH 09	Pearson's r	—			
	p-value	—			
	Lower 95% CI	—			
	Upper 95% CI	—			
BBCH 61	Pearson's r	0.493***	—		
	p-value	< 0.001	—		

	Lower 95% CI	0.328	—		
	Upper 95% CI	0.628	—		
BBCH 81	Pearson's r	0.569***	0.522***	—	
	p-value	< 0.001	< 0.001	—	
	Lower 95% CI	0.419	0.363	—	
	Upper 95% CI	0.688	0.652	—	
BBCH 89	Pearson's r	0.610***	0.445***	0.828***	—
	p-value	< 0.001	< 0.001	< 0.001	—
	Lower 95% CI	0.470	0.273	0.754	—
	Upper 95% CI	0.720	0.590	0.881	—

* $p < 0.05$, ** $p < 0.01$, *** $p < 0.001$.

Figure 2 plots the correlations between the analyzed phenotypes of table grape varieties cultivated at the Murfatlar vineyard center from 2000 to 2019. The trend lines, confidence intervals (blue line) and prediction intervals (green line) are shown in the graphs.

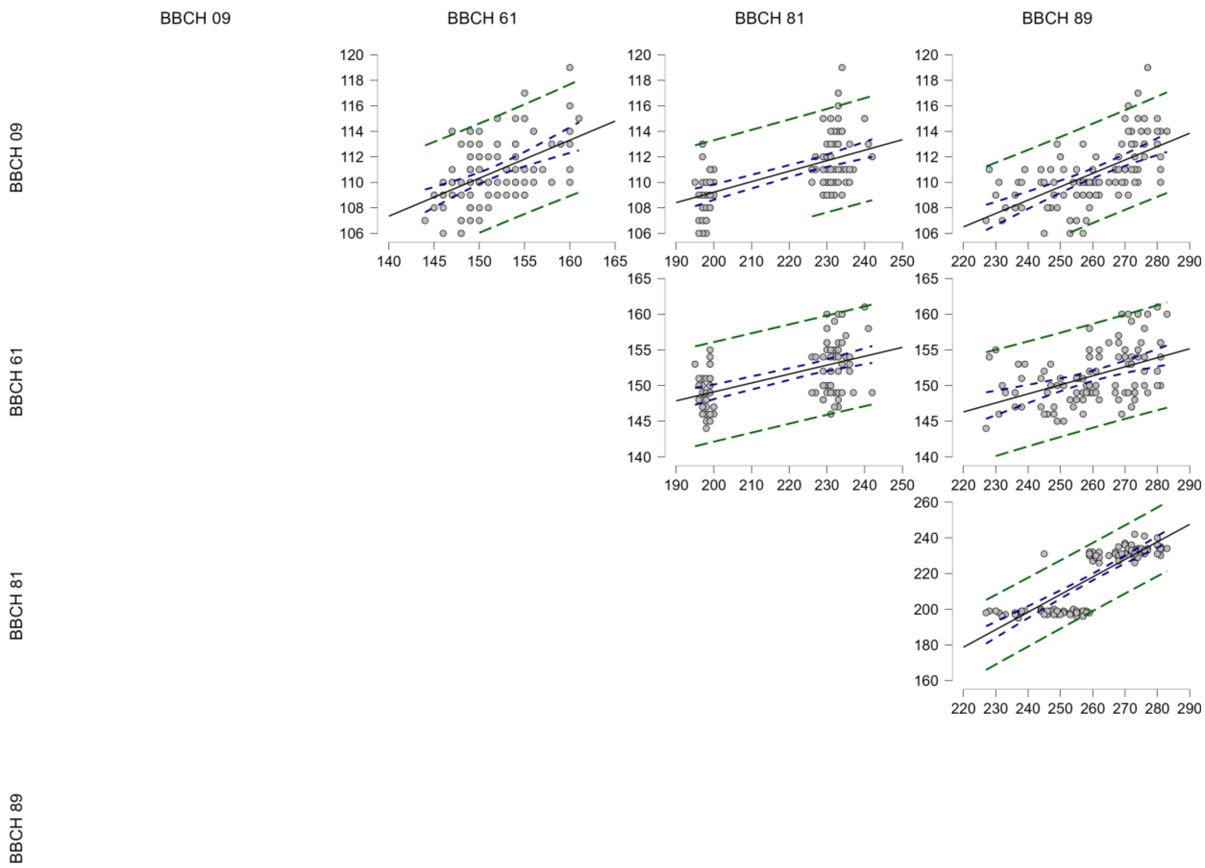

Figure 2. Correlations between the analyzed phenotypes of table grape varieties cultivated in Murfatlar vineyard in the period 2000-2019.

The graphical representation confirms the data presented above, by the existence of direct, positive correlations between the key phases of vegetation, in terms of the number of days recorded from January 1 to their onset, in the varieties studied. This indicates that the greater the number of days from January 1 to the time of recording the first vegetation phases (DOY), the longer the period to the subsequent phenophases (e.g., dormancy, maturity).

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As a result, we believe that the results of this study can be utilized in various ways. Disbudbreak, flowering, flushing, scorch and ripening are key phenological phases for the grapevine; their identification can be of economic importance through timely harvest management [47,48].

Correct identification of phenological phases helps determine the optimal time for applying various works and technologies correctly and on time. The impact of such studies has been noticed by several authors [39,49] who have focused on the importance of phenology for choosing the timing of treatments for disease and pest control, for vineyard irrigation while, the development of phenological maps can be useful for determining the ripening zones within the vineyard and differentiated harvesting. For example, studies have shown that late pruning after budbreak can delay phenology and, consequently, ripening. Therefore, knowledge of the effects of pruning timing on grape production and composition provides useful information for viticulturists to inform their vineyard management [50].

The elaboration of phenograms for the studied varieties under the existing conditions at Murfatlar can provide support for optimizing viticultural technologies in this vineyard, which is characterized by extreme climatic factors, including high temperatures and water deficits. Currently, in the Murfatlar vineyard, climatological studies indicate that the average annual temperature, heat balance, and number of days with scorching temperatures (> 35°C) have increased. At the same time, precipitation, particularly useful precipitation [51], has decreased. Additionally, the phenophase progression differs in the field compared to the protected cultivation of table grape varieties. In this context, recent studies propose the development of separate phenological calendars [52]. This approach, under current climatic conditions, proves useful not only for viticulture but also for other horticultural sectors such as fruit growing [9,53].

4. Conclusions

The study showed that the variety and climatic characteristics of the viticultural year phenologically influence all 5 fresh grape varieties studied.

The data recorded in this study highlight the fingerprint of terroir on certain table grape varieties, an important step in exploring phenotypic diversity among them.

These findings contribute to a deeper understanding of the impacts and consequences of climate change, providing valuable insights into the challenges faced by the wine sector.

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