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PHENOLOGICAL AND SOME ENO-CARPOLOGICAL TRAITS OF THIRTEEN NEW ROMANIAN GRAPEVINE VARIETIES FOR WHITE WINE (V*ITIS VINIFERA* L.) IN THE CONTEXT OF CLIMATE CHANGE

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Abstract

Thirteen new grapevine varieties for white wines' behaviour was studied between 2015-2019, under climate change conditions in the ampelografic collection of the UASVM Bucharest. During the experimentation period, as compared to the reference period (1981-2010), the average temperature during the growing season increased by 0.75°C, the average annual maximum temperatures by 1.26°C, number of hot days by 21, number of very hot days by 6.2 and Huglin index by 140 units. Phenological cycles (budburst to harvest) varied between 138.6 and 140.6 days, with Aromat de Iaşi and Crâmpoşie selecţionată - the most precocious varieties and Columna - the latest variety, as an average of 5 years of experimentation. Due to the high temperatures during the growing season, phenological stages were anticipated, the harvesting being anticipated by approximately 15-25 days. The highest value of sugar content of must was for Aromat de Iaşi variety (23.33°Brix) and the lowest value for Astra (19.38°Brix). Aromat de Iaşi, Crâmpoşie selecţionată and Şarba varieties have been distinguished by the best qualities.

Key words*: climate change, grapevine, new cultivars, phenology.*

INTRODUCTION

The vine and wine sector is one of the most developed sectors in Romanian agriculture, which largely benefited from the country accession to European Union in 2007 (Antoce & Călugăru, 2017). Romanian viticulture is recognized by the diversity of varieties used for obtaining high quality wine products: white, red, aromatic wines etc. Along with the recovery of the ancient, autochthonous varieties, many new ones have been obtained, widening, this way, the assortment of different vineyards. Grapevine varieties' diversity is permanently completed with new varieties in order to satisfy consumer preference and adaptation to climate change, to winter frost and to globalization. In the last 5 decades, 87 new grapevine varieties were obtained in Romania, out of which 17 for white wines (Glăman et al., 2018).

In the breeding programs, there were used, as genitors of valuable autochthonous, varieties such as Fetească albă, Fetească regală, Grasă de Cotnari, Tămâioasă românească, Crâmpoşie etc, alongside foreign ones, such as Chardonnay, Sauvignon, Pinot gris, Riesling italian, Muscat Ottonel etc. Germplasm resources and genetic diversity in grapes is an important basis for new varieties development (Antoce et al., 2015).

The new created grapevine varieties belongs to different maturation groups and have generally intermediate behavior in relation to their genitors. If their obtaining aimed initially at widening options in wine production, and creation of new varieties, with earlier or later ripening, or more resistant to diseases, today the interest focuses on the behavior of these new varieties in the current climate context. In Romania the climate change manifests at the entire country level (Bucur & Dejeu, 2016), and causes consequences as well as at the global viticulture (Jones et al., 2005).

Many recent studies have been carried out on the effects of climate change on vines phenology (Bucur & Dejeu, 2018), grape production, its quality (Bucur & Dejeu, 2013) and climate suitability of Romanian wine growing regions (Irimia et al., 2017).

Global warming requires detailed studies of varieties' behavior under the new conditions, to adopt appropriate measures in order to mitigate its effects and to continue ensuring wines typicity.

Phenology is the first component affected by climate change and it is a key parameter for varietal adaption (Fraga et al., 2015; Garcia de Cortazar-Atauri et al., 2017).

Collecting data about grapevine phenological stages can help grapegrowers to take better decision in the vineyard to improve efficiency, reduced labor cost and to protect vine health. Thus, canopy management (pruning, shoots and cluster thinning, shoots trimming, leaf removal, phytosanitary treatments, irrigation, fertilization) is applied at very precise moments of it is nesessary to follow and anticipate phenological development. Also, when establish the news plantations, it is necessary to choose the varieties with certain stages of budbreak and ripening of grapes, according to the local climatic and soil conditions, in order to obtain quality yield.

Knowing the evolution of grape ripening (veraison-ripening interval), is very important for determining the time of grape harvest and for the quality of the wines according to the type of wine that is to be obtained. For a planning of this cultural practices, the growers need to know an advance the date of occurrence of the main phenological stades: budburst, flowering, veraison, grape ripening (Chuine et al., 2013; Verdugo-Vásquez et al., 2017).

The increase in air temperature leads to a faster deployment of the main phenophases (budbreak, flowering, veraison and ripening), changes in the physiological and biochemical processes of the plant, vegetative growth, production and quality. Many studies have reported the accelerating effects of rising temperature on grapevine phenology (Martínez-Lüscher et al., 2016).

In climate change conditions, temperature is the main factor that determines the anticipation of the phenological stages (Sadras & Pertie, 2011; Bellia et al., 2007). Along with temperature, the phenology of grapevine is also influenced by solar radiation, UV-B radiation, water availability, CO_2 concentration, geografic location, altitude, nitrogen status (Jones & Davis, 2000; Schultz, 2008; Martínez-Lüscher et al., 2016; Cola et al., 2017; De Rességuier et al., 2018; Alikadic et al., 2019).

Warmer conditions due to climate change are generally associated with shorter petriods between phenological events and to earlier harvest dates (Tomasi et al., 2011). Premature ripening happens under warm temperatures and interferes with the balanced accumulation of sugars, acids, aroma profiles and berry coloration (Zyprian et al., 2018).

The advance of phenological cycle as a result of climate change, with ripening period occurring under warmer climatic conditions can modify the characteristics of the berries, wich contain less anthocyanin, less acids, more sugars and less aroma compounds (Duchêne et al., 2014). The shift of phenology and advancement of maturity was also reported by Ranca et al., 2008; Rotaru et al., 2013; Stroe et al., 2013; Irimia et al., 2017; Bucur & Dejeu, 2018.

Numerous comparisons between varieties, in terms of phenological development, in different wine regions of the world are analyzed in the scientific literature (Bellia et al., 2007; Rustioni et al., 2014a; Orlandi et al., 2015; Zapata et al. 2016; Verdugo-Vásquez et al., 2017).

Sadras et al., 2009, reported a high plasticity of budburst and flowering associated with high yield plasticity.

The knowleges about the phenotipic diversity of grapevine varieties or to be obtained by crossing opens new perspectives to mitigate the effect of climate warming on grapevine behaviour and grapes composition (Zyprian et al., 2018; Bigard et al., 2018). Torregrosa et al. (2017) proposed a program for the selection of varieties that limit the accumulation of sugars in berries, while maintaining other qualitative compounds.

In this study, there were followed the phenology and performance of 13 new white grape varieties created in Romania, according to the protocol established under COST Action FA 1003 (Rustioni et al., 2014b). The current values, averages for the 2015-2019 time period, are compared with averages for the 1981-2010 in order to find consequences determined by climate change in their behavior.

MATERIALS AND METHODS

Plant material. The current study was carried out at the grapevine collection located in the Southern part of Romania, at the University of Agronomical Science and Veterinary Medicine Bucharest (N Lat.: 44° 47' 07"; E Long.: 26° 07' 28"; alt. 87 m). The vines were planted at a distance of 2.2 x 1.2 m (3787 vines/ha), grafted on the Kober 5 BB rootstock, with spur pruned cordon on demi-high stem (0.6-0.7 m).
The new varieties analyzed in this study, all of them for white wine production (Table 1) are: green-yellow coloured varieties (Alb aromat, Aromat de Iași, Astra, Blasius, Columna, Crâmpoșie selecționată, Donaris, Furmint de Miniș, Miorița, Șarba), rose coloured varieties (Roz de Miniș, Selena) and grey coloured variety (Băbească gri).
The methodology for phenotyping, sampling, measurements and the methods for sugar content (by refractometer in °Brix values) and juice acidity (g tartaric acid. L^{-1}) followed the standardized protocols for phenotyping berry enological traits ratified by COST Action FA1003 project "East-West Collaboration for Grapevine Diversity Exploration and Mobilization of Adaptive Traits for Breeding" (Rustioni et al., 2014).
The sugar/acidity balance was estimated on the basis of the Brix/acidity ratio, that was obtained by dividing the °Brix value by % titratable acidity expressed as tartaric acid. All the activities were performed in four consecutive years, from 2015 to 2019.

Table 1. Grape varieties for white wine studied (Bucharest, 2015-2019)

Crt. no.	Cultivar	VIVC* no	Genitors	Color of berry skin
1	Alb aromat	23101	Tămâioasă românescă x IP165	green yelow
2	Aromat de Iași	20876	Fetească regală x Pinot gris	green yelow
3	Astra	632	Tămâioasă românescă open pollination	green yelow
4	Băbească gri	842	Băbească neagră-mutant	grey
5	Blasius	20959	(Iordană x Traminer roz) x (Raisin de Saint Pierre x Perla de Csaba)	green yelow
6	Columna	2787	Pinot gris x Grasă de Cotnari	green yelow
7	Crâmpoșie selecționată	3238	Crâmpoșie open pollination	green yelow
8	Donaris	3642	Bicane x Muscat de Hamburg	green yelow
9	Furmint de Miniș	16940	Furmint-mutant	green yelow
10	Miorița	7845	Coarnă neagră open pollination	green yelow
11	Roz de Miniș	10289	Clonal selection from a population of local varieties (probably Bacator roz)	rose
12	Selena	21558	(Iordană x Traminer roz) x (Raisin de Saint Pierre x Perla de Csaba)	rose
13	Șarba	10738	Riesling italian open pollination**	green yelow

* *Vitis* International Variety Catalogue; ** Confirmed by markers: Riesling italian x Muscat de Hamburg (Lacombe *et al.,* 2013)

Climatic conditions. For this study, there were used weather data recorded at Bucharest-Baneasa meteorological station for the experimental period (2015-2019), as compared to the reference period (1981-2010). There were studied the following variables: average annual temperature (AAT); average temperature in the growing season (ATGS); average temperature in summer (ATS); average annual minimum temperature (AAT_{min}); absolute minimum temperature (AT_{min}); average annual maximum temperature (AAT_{max}); average of the warmest month's maximum temperatures ($AWMT_{max}$); average maximum temperature in summer (AST_{max}); number of hot days (T_{max} > 30°C); number of very hot days (T_{max} > 35°C); annual total precipitation (ATP); total precipitation in the growing season (TPGS); total precipitation in summer months (TPS). Monthly average temperatures were used to evaluate a set of bioclimatic indices commonly used in viticulture: Huglin index (HI, Huglin, 1978), Winkler index (WI, Winkler et al., 1974) and cool night index (CNI, Tonietto & Carbonneau, 2004).
Phenological data. The four main phenophases (budburst, flowering, veraison, harvesting maturity) were followed, according to BBCH (**B**iologische **B**undesansalt und **C**hemische Industrie), modified under the COST FA 1003

Action (Lorenz et al., 1994; Rustioni et al., 2014b). According to the recorded data, 50% of buds, flowers and grapes reached the respective phenological stages: BBCH 008 (green tips clearly visible) - budburst; BBCH 605 (flowers are open) - flowering; BBCH 805 (changing of berries color, or softening) - veraison and BBCH 809 (Brix according to the cultivar) - berries ripe for ripening.
Each data set was analyzed using variance analysis, One Way ANOVA, post-hoc Tukey HSD $p<0.05$.

RESULTS AND DISCUSSIONS

Changes in climate characteristics of the study area, between 1981-2010 and 2015-2019 time periods

The main climatic parameters of the experimental period compared to the reference period are presented in Table 2. During the studied period (2015-2019), higher temperatures were recorded, as compared to the reference period (1981-2010): the AAT was higher by 0.61°C; the ATGS (IV-X) increased by 0.32°C and $AWMT_{max}$ by 0.31°C. The highest increase (1.26°C) was recorded at average annual maximum temperature (AAT_{max}).
Average temperature for the growing season (17-19°C) includes the Southern part of Romania in warm climate maturity grouping (Jones et al., 2005; White et al., 2006; Ramos et al., 2018; Tomasi et al., 2011; Neethling et al., 2012), similar to some wine region from Italy (Piedmont, Chianti), France (Loire Valley, Bordeaux, Rhone Valley), USA (Margaret River, Northern and Coastal California) etc.
The current average of the ATGS maintains local climate in the *warm* class suitable for the Cabernet Sauvignon, Merlot, Cinsaut varieties (Huglin, 1978), but it approaches by the upper limit of 19°C which indicates the transition to the *hot* climate suitable only for the production of table grapes. Compared with the reference period (1981-2010), during the experimentation period (2015-2019), the number of hot days in the growing season (Tmax > 30°C) increased from 46 to 67, and the number of very hot days (Tmax > 35°C) it doubled, from 6 to 12.2.
Both annual total precipitation and the one in the growing season had a small variation. The increase in ATP by 20 mm in the reference period does not have the potential to balance the increased values of evapotranspiration generated by temperature increases.
Bioclimatic indices (Huglin index, Winkler index and Cool night index) also recorded higher values during the current period, as compared to the reference period, as follows: an increase of 140 units for the Huglin index; an increase of 69 units for the Winkler index; an increase of 1.09°C for the Cool night index. By its increase, the Huglin index passes from the temperate – warm class HI+1 between 1981-2010, to the warm class HI+2 during the recent period. This also changes the climate profile to wich local varieties were adapted and creates the climate context for the growing of new wine grape varieties.
The Winkler index current average maintains in the climate profile specific to Regions III (suitable for high production of standard to good quality wine table wines) but with an increased value approaching climate suitability to that specific to Regions IV (acceptable table wine quality at best). A similar evolution for the CI wich maintains in the class of very cool nights, less suitable to grapes ripening, but with an increased value that reveal the evolution towards the superior cool night class.

Phenology data for the 2015-2019 time-period

The first effect of temperature raising is on advance of phenological stages of grapevine. The differences in the timing of phenological stages and the interval between them are given to genetic factors, climate and soil conditions and viticultural practices (Bucur & Dejeu, 2018). Table 3 shows the average day of the year (DOY) and standard deviations of the four phenological stages of grapevine (budbreak, flowering, veraison and harvest) for the period between 2015 and 2019.
The time of **budbreak** occured on average 106.4 DOY (April 16), earlier for Aromat de Iași and Crâmpoșie selecționată varieties (104.4) and later for Columna variety (110.6). Considering year-to-year variability in budburst, Donaris exhibited the lowest variability (SD ± 2.3 days) while Crâmpoșie selecționată has the greatest variation (SD ± 4.5 days). Standard deviations indicate a moderate interannual variability, ranging from 5 to 9 days.

Flowering occurred on average at DOY 150.1 (May 30), earlier for Crâmpoșie selecționată variety (147.4) and later for Furmint de Miniș (152.0), the differences between varieties being relatively small. Donaris and Roz de Miniș exhibited the least year-to-year variation (SD ± 5.3 days) while Selena had a highest year-to-year variation (SD ± 6.5 days).

Veraison was registered on average at DOY 215.4 (August 03) earlier for Alb aromat variety (211.4) and later for Selena variety (220.0). Roz de Miniș had the lowest year-to-year variation of ± 2.1 days while Columna varied by ± 8.9 days during 2015-2019.

The average day of the year for **grapes ripening**, for the 5 studied years, was the earliest for Aromat de Iași (243.2) and the latest for Roz de Miniș and Selena (251,2), this meaning the 8th of September on average, for the two varieties. Miorița exhibited the lowest year-to-year variability (SD ± 3.4 days) while Alb aromat showed the highest year-to-year vari-ation (SD ±7.6 days). The results concerning the main phenological timing across the growing season shown that there are not always strong relationships between growth events.

Table 2. The main climatic indicators of the experimentation period (2015-2019) compared to the multiannual average (1981-2010)

Climatic parameters and bioclimatic indices	Average	Years					Average	Diference
	1981-2010	2015	2016	2017	2018	2019	2015-2019	2015-2019 / 1981-2010
Average annual temperature (AAT), ºC	**11.55**	12.05	11.88	11.74	12.21	12.92	**12.16**	**+ 0.61**
Average temperature in the growing season (ATGS), ºC (IV-X)	**18.07**	17.95	18.13	17.99	19.33	18.53	**18.39**	**+ 0.32**
Average temperature in summer (ATS), ºC (VI-VIII)	**22.50**	2.,3	22.92	22.78	22.83	23.05	**22.78**	+ 0.28
Average annual minimum temperature (AATmin), ºC	**5.03**	5.88	5.78	5.44	6.38	6.57	**6.01**	+ 0.98
Average of absolute minimum temperature, (ATmin), ºC	**-16.99**	-20.40	-19.70	-21.70	-21.70	-15.50	**-19.80**	-1.01
Average annual maximum temperature (AATmax), ºC	**17.05**	18.22	17.98	18.04	18.03	19.28	**18.31**	**+ 1.26**
Average warmest month July maximum temperature (AWMTmax), ºC	**29.87**	3.87	27.76	30.16	28.87	29.64	**29.66**	- 0.21
Average maximum temperature in summer (ASTmax), ºC (VI-VIII)	**29.01**	29.83	30.17	30.01	29.81	30.5	**30.06**	**+ 1.05**
Number of hot days (T_{max} > 30°C)	**46**	62	75	66	71	62	**67**	**+ 21**
Number of very hot days (T_{max} > 35°C)	**6**	23	10	13	6	9	**12.2**	**+ 6.2**
Annual total precipitation (ATP), mm	**608**	632	694	661	623	529	**628**	+ 20
Total precipitation in the growing season (TPGS), mm (IV-X)	**428**	371	514	415	312	385	**400**	- 28
Total precipitation in summer (TPS), mm (VI-VIII)	**198**	150	164	155	228	142	**168**	- 30
Huglin index (HI, Huglin, 1978)	**2346**	2422	2497	2408	2646	2458	**2486**	**+ 140**
Winkler index (WI, Winkler, 1974)	**1726**	1701	1740	1710	1997	1825	**1795**	+ 69
Cool night index (CI, Tonietto and Carbonneau, 2004)	**10.45**	12.6	11,06	12.16	11.30	10.60	**11.54**	+ 1,09

Table 3. Mean day of year (DOY) of the phenological stages (budburst; flowering; veraison and harvest) and the corresponding standard deviations (SD in days), for grapevine varieties for white wine (2015-2019)

Variety	Budburst (50%)	Flowering (50%)	Budburst-Flowering (days)	Veraison (50%)	Flowering-Veraison (days)	Harvest	Veraison-Harvest (days)	Budburst-Harvest (days)
Alb aromat	105.8 ± 4.2[a]	150.4 ± 6.1[a]	44.6 ± 6.5a	211.4 ± 5.1[a]	61.0 ± 4.6a	244.0 ± 7.6a	32.6± 12.5a	138.6 ± 9.1a
Aromat de Iași	104.4 ± 3.2[a]	148.8 ± 5.8[a]	44.4 ± 6.7a	213.2 ± 7.8[a]	64.4 ± 8.7a	243.2 ± 6.8a	30.0 ± 7.6a	138.8 ± 5.3a
Astra	106.8 ± 3.1[a]	150.6 ± 5.7[a]	43.8 ± 4.6a	215.0 ± 4.9[a]	64.4 ± 1.5a	249.8 ± 3.7a	36.4 ± 8.1a	143.0 ± 4.1a
Băbească gri	106.2 ± 3.3[a]	149.8 ± 5.5[a]	43.6 ± 5.8a	211.6 ± 4.5[a]	61.8 ± 2.7a	246.4 ± 5.7a	34.8 ± 8.9a	140.2 ± 8.5a
Blasius	107.2 ± 3.6[a]	151.6 ± 5.6[a]	44.4 ± 5.6a	214.4 ± 4.9[a]	62.8 ± 3.5a	249.8 ± 4.3a	35.4 ± 3.9a	142.6 ± 5.2a
Columna	110.6 ± 4.3[a]	151.0 ± 6.4[a]	40.4 ± 5.9a	215.0 ± 8.9[a]	64.0 ± 6.8a	247.8 ± 3.6a	32.8± 11.4a	137.2 ± 5.6a
Crâmpoșie sel.	104.4 ± 4.5[a]	147.4 ± 5.4[a]	43.0 ± 6.6a	219.2 ± 4.6[a]	71.8 ± 2.8a	250.6 ± 4.3a	31.6 ± 6.2a	146.4 ± 7.6a
Donaris	106.4 ± 2.3[a]	151.2 ± 5.3[a]	44.8 ± 5.9a	214.4 ± 6.2[a]	63.2 ± 1.3a	244.0 ± 7.4a	29.6± 11.7a	137.6 ± 7.1a
Furmint de Miniș	107.0 ± 2.4[a]	152.0 ± 5.8[a]	45.0 ± 5.2a	219.4 ± 8.2[a]	67.4 ± 6.8a	248.2 ± 3.6a	28.4 ± 9.1a	141.2 ± 4.8a
Miorița	107.4 ± 3.8[a]	151.8 ± 5.8[a]	44.4 ± 5.6a	217.4 ± 5.0[a]	65.6 ± 2.5a	248.6 ± 3.4a	31.2 ± 5.3a	142.4 ± 6.6a
Roz de Miniș	107.4 ± 3.4[a]	151.0 ± 5.3[a]	43.6 ± 5.7a	219.0 ± 2.1[a]	68.0 ± 4.1a	251.2 ± 4.3a	32.2 ± 3.9a	143.8 ± 6.4a
Selena	106.4 ± 2.9[a]	148.6 ± 6.5[a]	42.2 ± 6.8a	220.0 ± 4.8[a]	71.4 ± 1.8a	251.2 ± 3.9a	30.8 ± 6.1a	144.4 ± 4.0a
Șarba	105.4 ± 2.8[a]	149.2 ± 5.8[a]	43.8 ± 6.3a	213.8 ± 3.8[a]	64.6 ± 4.6a	246.2 ± 5.6a	32.4 ± 6.5a	140.8 ± 6.4a
Mean	106.4 (April 16)	150.1 (May 30)	43.7	215.4 (August 03)	65.2	247.4 (September 04)	32.1	141.1
Minimal value	104.4	147.4	40.4	211.4	61.0	243.2	28.4	137.2
Maximal value	110.6	152.0	45.0	220.0	71.8	251.2	36.4	146.4

The intervals between phenological events also show some variability, ranged from 40.4 days (Columna) to 45.0 days Furmint de Miniș for budbreak-flowering, from 61.0 days (Alb aromat) to 71.8 days (Crâmpoșie selecționată) for flowering-veraison, from 28.4 days (Furmint de Miniș) to 36.4 days (Astra) for veraison-ripening, and from 137.2 days (Columna) to 146.4 days (Crâmpoșie selecționată) for budbreak-ripening.

As compared to the reference data in literature on the maturity stages (Indreaş & Vişan, 2001; Rotaru, 2009; Stroe, 2021), grapes ripening was anticipated with 5-15 days for medium maturation varieties (Aromat de Iaşi, Donaris, Şarba) and 23-28 days for late maturation (Mioriţa, Crâmpoșie selecționată, Băbească gri, Selena).

Compared with the data presented by Drappier et al. (2019) for Bordeaux vineyard, the data obtained in our study for the interval between flowering and veraison are similar (approximately 65 days), while the veraison-ripening period is lower (on average 32 compared to 45 days).

The lowest intervarietal variability was found in flowering (4.6 days) and the highest one in veraison (8.6 days). Standard deviation (SD) showed the lowest interannual variability in budburst (from 2.3 to 4.5 days) and the highest one in veraison (from 2.1 to 8.9).

In Table 4, the main grape bunch and berry characteristics are presented for the 13 new white grape varieties. Roz de Miniș variety distinguished by the highest value of bunch weight (399.34 ± 24.79 f) and Columna by the minimum value (167.51 ± 22.87c). In most varieties, berries weight, on average, between 2.40 ± 0.25d g/berry (Selena) and 3.23 ± 0.59bd g (Alb aromat). All studied varieties have a spherical berry shape with small deviations, and medium length and width (OIV codes: 220, 221 and 223).

Grape production (kg/vine) was significantly affected by the minimum harmful temperatures in winter (Tmin < -20ºC), especially during 2014/2015 and 2015/2016 periods. The most affected variety was Columna (2.13 ± 1.33a kg/vine).

Warmer climate conditions are associated with increased sugar accumulation and decreased titratable acidity. As for the sugar concentration (ºBrix), high levels are found in most varieties (Table 5). Significant maximum sugar accumulations were recorded to Aromat de Iași (23.33 ± 0.88ºBrix), followed by Şarba (23.06 ± 0.87ºBrix) and minimum sugar accumulations to varieties Astra (19.38 ± 1.29ºBrix) and Columna (19.98 ± 0.79ºBrix).

The highest titratable acidity concentration was registered in Aromat de Iași (7.81 ± 0.68 $g.L^{-1}$ acid tartric) and the lowest in Roz de Miniș (5.33 ± 0.76 $g.L^{-1}$ acid tartric).

In order to appreciate the optimal grape maturity, it is important to calculate glucoacidimetric index and to compare it with optimal values (Shellie, 2007; Irimia, 2012). Most varieties are closer to optimum maturity. The qualitative characteristics of most studied varieties showed the possibility to obtain good quality wines, starting from a sugar content higher than 21 ºBrix.

Table 4. Grapes quantitative parameters at harvesting time for grapevine varieties for white wine* (2015-2019)

Crt. no.	Variety	Bunch weight (g)	Berry weight (g)	Yield (kg / vine)
1	Alb aromat	288.39 ± 35.45 b	3.23 ± 0.59 bd	3.00 ± 1.24 a
2	Aromat de Iași	191.46 ± 22.12 c	2.81 ± 0.40 bc	3.20 ± 0.74 a
3	Astra	217.57 ± 12.46 cd	3.09 ± 0.30 bc	2.44 ± 0.75 a
4	Băbească gri	186.69 ± 14.24 c	2.85 ± 0.32 bcd	2.29 ± 0.98 a
5	Blasius	185.39 ± 39.55 c	3.17 ± 0.67 b	3.08 ± 1.30 a
6	Columna	167.51 ± 22.87 c	2.59 ± 0.18 cd	2.13 ± 1.33 a
7	Crâmpoșie selecționată	220.04 ± 31.97 ce	3.08 ± 0.25 b	3.12 ± 0.70 a
8	Donaris	195.97 ± 22.08 c	3.13 ± 0.24 b	2.49 ± 0.92 a
9	Furmint de Miniș	203.65 ± 40.33 c	3.05 ± 0.20 bc	2.83 ± 1.22 a
10	Miorița	206.89 ± 38.62 ce	2.92 ± 0.45 bc	2.73 ± 1.29 a
11	Roz de Miniș	399.34 ± 24.79 f	3.17 ± 0.35 b	2.62 ± 0.73 a
12	Selena	189.92 ± 37.89 c	2.40 ± 0.25 d	2.78 ± 1.10 a
13	Șarba	184.86 ± 50.64 c	2.76 ± 0.58 bcd	2.62 ± 0.88 a
	Minimal value	167.51	2.40	2.13
	Maximal value	399.34	3.23	3.20

Table 5. Qualitative parameters at harvesting time for grapevine varieties for white wine* (2015-2019)

Crt. no.	Variety	Sugar content (ºBrix)	Titratable acidity ($g.L^{-1}$ tartaric acid)	Glucoacidimetric index
1	Alb aromat	20.45 ± 0.89 ab	5.52 ± 0.63 c	37.52 ± 4.59 c
2	Aromat de Iași	23.33 ± 0.88 cb	7.81 ± 0.68 a	30.10 ± 3.14 b
3	Astra	19.38 ± 1.29 a	7.78 ± 0.61 a	25.00 ± 2.05 bd
4	Băbească gri	20.87 ± 1.02 b	7.12 ± 0.71 a	29.66 ± 4.01 b
5	Blasius	20.93 ± 0.86 b	7.79 ± 0.46 a	27.00 ± 2.57 bd
6	Columna	19.98 ± 0.79 a	6.51 ± 0.32 ca	30.80 ± 2.32 b
7	Crâmpoșie selecționată	21.97 ± 1.33 cb	6.78 ± 0.76 ca	32.83 ± 4.58 bc
8	Donaris	21.92 ± 1.08 cb	6.77 ± 0.67 ca	32.80 ± 4.57 bc
9	Furmint de Miniș	21.77 ± 0.92 cb	7.50 ± 0.77 a	29.34 ± 3.56 b
10	Miorița	20.03 ± 1.22 a	7.18 ± 0.47 a	28.07 ± 2.97 b
11	Roz de Miniș	21.05 ± 1.42 b	5.33 ± 0.76 b	40.46 ± 7.42 c
12	Selena	21.83 ± 1.11 b	7.21 ± 1.00 a	30.95 ± 5.46 b
13	Șarba	23.06 ± 0.87 c	6.97 ± 1.21 a	35.39 ± 6.93 b
	Minimal value	19.38	5.33	25.00
	Maximal value	23.33	7.81	40.46

*Average values ± standard errors (n=3). The letters in the brackets show the statistical difference among results for grape varieties for $p<0.05$. For the same compound, a common letter for 2 or more variants shows no significant difference among them; One Way ANOVA, post-hoc Tukey HSD $p<0.05$.

Comparing the qualitative parameters obtained in this study with those reported in Ampelography, vol. IX for the period 1980-2000, differences can be observed. Thus, during the experimental period (2015-2019) an anticipation of the grape ripening period was found by approximately 15 days (for the Aromat de Iași, Columna, Furmint de Miniș varieties) and up to 30 days (for the Băbească gri, Crâmpoșie selecționată, Roz de Miniș and Selena) (Table 6).

Increased accumulations of sugars were also recorded, between + 14 g/L (Şarba) and + 33 g/L (Aromat de Iasi), compared to the period 1980-2000. In most varieties the titratable acidity recorded lower values. The optimal values of the glucoacidimetric index are between 30-50, for the varieties Alb aromat, Aromat de Iași, Columna, Donaris, Roz de Miniș, Selena and Şarba (Table 6).

Table 6. The main characteristics of the new varieties for white wines obtained in the experimental period (2015-2019), compared to the reference period (1980-2000)

Crt. no.	Variety	Period of grapes maturation		Sugar content (ºBrix)		Titratable acidity (g.L^{-1} tartaric acid)		Glucoacidimetric index	
		1980-2000*	2015-2019	1980-2000*	2015-2019	1980-2000*	2015-2019	1980-2000*	2015-2019
1	Alb aromat	IV-V	IV	19.7-22.0	20.5	5.4-6.9	5.52	37-32	37
2	Aromat de Iași	IV	III	17.0-20.0	23.3	6.1-6.7	7.81	43-30	30
3	Astra	V-VI	**IV**	16.4-20.4	19.4	9.2-9.9	7.78	18-21	25
4	Băbească gri	VI	**IV**	16.8-19.5	20.9	9.2-10.3	7.12	18-19	29
5	Blasius	V-VI	**IV**	19.6-20.0	20.9	8.9-10.5	7.79	22-19	27
6	Columna	V	IV	18.4-22.0	20.0	7.7-9.2	6.51	24-23	31
7	Crâmpoșie sel.	VI	**IV**	18.0-20.6	21.9	6.4-7.0	6.78	28-29	32
8	Donaris	IV	IV	18.0-22.0	21.9	7.7-8.6	6.77	23-26	32
9	Furmint de Miniș	V	IV	18.0-19.5	21.8	6.1-8.7	7.50	29-22	29
10	Miorița	V-VI	**IV**	16.5-18.0	20.0	8.6-11.5	7.18	19-16	28
11	Roz de Miniș	VI	**IV**	13.6-18.2	21.1	5.5-6.6	5.33	25-28	39
12	Selena	VI	**IV**	18.8-21.0	21.8	8.1-9.2	7.21	23-30	30
13	Șarba	V	IV	18.7-21.7	23.1	7.5-7.9	6.97	25-27	33

*after Ampelography, vol. IX.

CONCLUSIONS

The study has shown that climate warming influences, to a greater or lesser extent, all the 13 new varieties for white wines.

During the experimentation period (2015-2019) an increase of the average annual temperature with 0.61ºC was observed, and of the average maximum summer temperature with 1.05ºC, compared to the reference period (1981-2010). There was also a marked increase in heat waves, represented by the number of days with $T_{max} > 30$ºC and $T_{max} > 35$ºC. In the last five years was an increase of 140 units for the Huglin index which passes from temperate - warm class (HI + 1) to the warm class (HI + 2).

There have been significant changes in grapevine phenology, as well as in the quantity and quality of grape production.

The highest differences compared to reference period, were recorded at grape ripening, the anticipation being between 11.5-14.3 days. These differences were due to the increase of the maximum temperatures in the summer season, with 1.05ºC.

The average length of the budbreak-harvest cycle for the studied period (2015-2019) and for all varieties was shortened, reaching 137.2 to 146.4 days. The longest phenological cycle (from budburst to grapes ripening) were observed at Crâmposie selecționată variety (146.4 days), due to early budburst and late maturation.

The best behavior under quantitative terms, but mainly under qualitative ones, was found in Aromat de Iaşi, Şarba, Crâmposie selecționată and Băbească gri varieties.

Considering the anticipation of a more intense climate warming for the future (IPCC, 2018), it is necessary to promote varieties with moderate accumulations of sugars, with late grape maturation, in order to avoid ripening during excessive temperature periods.

The exploration of the genetic capacity of the different new varieties of grapevine under the current conditions, provides an important means of adaptation to the climatic warming. The recorded data in our study allow understanding the local diversity of new grapevine varieties for white wines, which is an important step to explore the phenotypic diversity among grapevine varieties.

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REFERENCES

Antoce, A.O., Stroe, M.V., & Cojocaru, G.A. (2015). Tentative application of an electronic nose to the study of the parentage of Romanian grape varieties Șarba and Alb aromat. *Agriculture and Agricultural Science Procedia*, vol. 6, 110-117.

Antoce, A.O., & Călugăru, L.L. (2017). Evolution of grapevine surfaces in Romania after accession to European Union – period 2007–2016. *40th World Congress of Vine and Wine*, BIO Web of Conferences 9, 03018, 1-7.

Alikadic, A., Pertot, I., Eccel, O., & Furlanello, C. (2019). The impact of climate change on grapevine phenology and the influence of altitude. *Agricultural and Forest Meteorology*, 271, 73-82.

Bellia, S., Douguedroit, A., & Seguin, B. (2007). Impact du réchauffement sur les étapes phénologiques du développement du Grenache et de la Syrah dans les Côtes du Rhône et les Côtes de Provence (1976-2000). *Réchauffement climatique, quels impacts probables sur les vignobles?* Dijon, 28-30 mars.

Bigard, A., Berhe, D.T., Maoddi, E., Sire, Y., Boursiquot, J.M., Ojeda, H., Péros, J.P., Doligez, A., Romieu, C., & Torregrosa, L. (2018). *Vitis vinifera* L. fruit diversity to breed varieties anticipating climate changes. *Front. Plant Sci.*, 9, 455.

Bucur, G.M., & Dejeu, L. (2013). Effects of climate change on grape yield and quality on a long-terme experience. *Lucrări ştiinţifice USAMV „Ion Ionescu de la Brad" Iaşi, Seria Horticultură*, *56*(1), 269-274.

Bucur, G.M., & Dejeu, L. (2016). Research on some aspects regarding climate change in romanian viticulture. *AgroLife Scientific Journal, 5*(2), 24-27.

Bucur, G.M., & Dejeu, L. (2018). Research on phenotyping and eno-carpological traits of twenty-three new romanian table grape varieties (*Vitis vinifera* L.). *Agriculture for Life, Life for Agriculture Conference Proceedings, Sciendo, 1*, 268-275.

Chuine, I., García de Cortázar-Atauri, I., Kramer, K., & Hänninen, H. (2013). Plant development models, in: Phenology: An Integrative Environmental Science. *Springer*, 275–293.

Cola, G., Failla, O., Maghradze, D., Megrelidze, L., & Mariani, L. (2017). Grapevine phenology and climate change in Georgia. *Int J Biometeorol, 61*(4):761-775.

De Rességuier, L., Le Roux, R., Petitjean, T., Mary, S., Quénol, H., & Van Leeuwen, C. (2018). Variability of climate, water and nitrogen status and its influence on vine phenology and grape composition inside a small winegrowing estate. *Web of Conferences 50, 01016 XII Congreso Internacional Terroir*, 1-5.

Drappier, J., Thibon, C., Rabot, A., & Geny-Denis, L. (2019). Relationship between wine composition and temperature: Impact on Bordeaux wine typicity in the context of global warming – Review. *Food Science and Nutrition, 59*(1), 14-30.

Duchêne, E., Huard, F., & Pieri, P. (2014). Grapevine and climate change: what adaptations of plant material and training systems should we anticipate? *J. Int. Sci. Vigne Vin*, Special Laccave*,* 59-67.

Fraga, H., Costa, R., Moutinho-Pereira, J., Correia, C. M., Dinis, L. T., Goncalves, I., Silvestre, J., Eiras-Dias, J., Malheiro, A. C., & Santos, J. A. (2015). Modeling phenology, water status, and yield components of three Portuguese grapevines using the STICS crop model. *American Journal of Enology and Viticulture, 66*(4), 482-491.

García de Cortázar-Atauri, I., Duchêne, E., Destrac-Irvine, A., Barbeau, G., de Rességuier, L., Lacombe, T., Parker, A. K., Saurin, N., & van Leeuwen, C. (2017). Grapevine phenology in France: from past observations to future evolutions in the context of climate change. *Oeno One, 51*(2), 115-126.

Glăman, Gh., Dejeu, L., Brînduşe, E., Șerdinescu, A., & Ion, M. (2018). *Ampelografia României, vol. IX.* Bucharest, RO: Ceres Publishing House.

Huglin, P. (1978). Nouveau mode d'évaluation des possibilités héliothermiques d'un milieu viticole. *Symposium International sur l'Écologie de la Vigne, l, Constanta, Roumanie.* Ministère de l'Agriculture et de l'Industrie Alimentaire, 89-98.

Indreaș, A., & Vișan, L. (2001). *Principalele soiuri de struguri de vin cultivate în România.* Bucharest, RO: Ceres Publishing House.

Irimia, L.M. (2012). *Biologia viței-de-vie.* Iași, RO: Ion Ionescu de la Brad, Publishing House.

Irimia, L.M., Patriche, C.V., & Roşca, B. (2017). Changes in oenoclimate aptitude index characterizing climate suitability of Romanian wine growing regions. *Applied Ecology and Environmental Research*, *15*(4), 755-767.

Jones, G.V., & Davis, R.E. (2000). Climate Influences on Grapevine Phenology, Grape composition, and Wine Production and Quality for Bordeaux, France. *American Journal of Enology and Viticulture*, *51*(3), 249-261.

Jones, G.V., White, M.A., Cooper, O.R., & Storchmann, K. (2005). Climate change and global wine quality. *Climatic change 73*(3), 319-343.

Lacombe, T., Boursiquot, J.M., Laucou, V., Di Vecchi Staraz, M., Peros, J.P., &This, P. (2013). Large-scale parentage analysis in an extended set of grapevine cultivars (*Vitis vinifera* L.). *Theoretical Applied Genetics 126* (2), 401-414.

Lorenz, D.H., Eichhorn, K.W., Bleiholder, H., Klose, R., Meier, U., & Weber, E. (1994). Phänologische Entwicklungsstadien der Weinrebe (*Vitis vinifera* L. ssp. vinifera). *Vitic. Enol. Sci. 49*, 66-70.

Martínez-Lüscher, J., Kizildeniz, T., VišnjaVuceti, V., Dai, Z., Luedeling, E., van Leeuwen, C., Gomès, E., Pascual, I., Irigoyen, J., Morales, F., & Delrot, S. (2016). Sensitivity of Grapevine Phenology to Water Availability, Temperature and CO_2 Concentration. *Frontiers in Environmental Science, 4*, Article 48, 1-13.

Neethling, E., Barbeau, G., Bonnefoy, C., & Quénol, H. (2012). Change in climate and berry composition for grapevine varieties cultivated in the Loire Valley. *Clim Res 53*, 89-101.

OIV (2016): State of the Vitiviniculture World Market. http://www.oiv.int/en/tehnical-standards-and-documents/statistical-analysis/state-of-vitiviniculture. Accessed 06 March 2019.

Orlandi, F., Bonofiglio, T., Aguilera, F., & Fornaciari, M. (2015). Phenological characteristics of different winegrape cultivars in Central Italy. *Vitis 54*, 129-136.

Ramos, M.C., Jones, G.V., & Yuste J. (2018). Phenology of Tempranillo and Cabernet Sauvignon varieties cultivated in the Ribera del Duero DO: observed variability and predictions under climate change scenarios. *OENO-One 52*(1), 31-44.

Ranca, A., Boloș, P., & Guluță, E. (2008). Climate changes of the last 10 years in the Murfatlar vineyard and their influence on the behaviour of the specific grapevine varieties of this vineyard. *31st World Congress of Vine and Wine, Verona, Italia.*

Rotaru, L. (2009). *Soiuri de viță de vie pentru struguri de vin*. Iași, RO: Ion Ionescu de la Brad, Publishing House.

Rotaru, L., Colibaba, L.C., & Prisăcaru, A.I. (2013). Studies of the behavioural tendencies of some grape varieties for white wines in Moldavian vineyards, under the influence of climatic changes. *Lucrări ştiinţifice USAMV Iaşi, Seria Horticultură, 56*(2), 303-308.

Rustioni, L., Cola, G., Fiori, S., Failla, O., Bacilieri, R., Maul, E., Eiras Dias, J.E., Brazão, J., Kocsis, L., Lorenzini, F., Maghradze, D., Chipashvili, R., Maletic, E., Preiner, D., Molitor, D., Muljukina, N., Muñoz-Organero, G., Musayev, M., Nikolaou, N., Risovanna, V., Ruisa, S., Salimov, V., Savin, G., Cornea, V., Savvides, S., Schneider, A., Skala, O., Ujmajuridze, L. (2014)a. Application of standard methods for the grapevine (Vitis vinifera L.) phenotypic diversity exploration: Phenological traits. *Acta horticulturae 1032*, 253-260.

Rustioni, L., Maghradze, D., Popescu, C.F., Cola, G., Abashidze, E., Aroutiounian, R., Brazao, J., Coletti, S., Cornea, V., Dejeu, L., Dinu, D., Eiras Dias, J.E., Fiori, S., Goryslavets, S., Ibáñez, J., Kocsis, L., Lorenzini, F., Maletic, E., Mamasakhlisashvili, L., Margaryan, K., Mdinaradze, I., Memetova, E., Montemayor, M.I., Muñoz-Organero, G., Nemeth, G., Nikolaou, N., Raimondi, S., Risovanna, V., Sakaveli, F., Savin,G., Savvides, S., Schneider, A., Schwander, F., Spring, J.L., Pastore, G., Preiner, D., Ujmajuridze, L., Zioziou, E., Maul, E., Bacilieri, R., & Failla, O. (2014)b. First results of the European grapevine collections' collaborative network: validation of a standard eno-carpological phenotyping method. *Vitis 53*, 219-226.

Sadras, V.O., Reynolds, M.P., Vega, A.J., Petrie, P.R., & Robinson, R. (2009). Phenotypic plasticity of yield and phenology in wheat, sunflower and grapevine. *Field Crops Research 110*, 242–250.

Sadras, V.O., & Petrie, P.R. (2011). Climate shifts in south-eastern Australia: early maturity of Chardonnay, Shiraz and Cabernet Sauvignon is associated with early onset rather than faster ripening. *Australian Journal of Grape and Wine Research, 17* (2), 199-205.

Shellie, K. (2007). Viticultural Performance of Red and White Wine Grape Cultivars in Southwestern Idaho. *HortTechnology*, *17*(4), 595-603.

Stroe, M. V., Matei, D., Damian, I., Ispas, S., & Dumitru, E. (2013). Research regarding local vineyards germplasm resource monitoring conditions determined local climate change. *36 th World Congress of Vine and Wine*, Bucharest (Romania), 194-195.

Stroe, M.V. (2021). Genetic diversity the viticultural germplasm fund of Romania – news accessions. *Scientific Papers. Series B, Horticulture, LXV*(1), 342-351.

Schultz, H.R. (2008): Climate change and viticulture: A European perspective on climatology, carbon dioxide and UV-B effects. *Australian Journal of Grape and Wine Research 6*(1), 2-12.

Tomasi, D., Jones, G.V., Giust, M., Lovat, L., & Gaiotti, F. (2011). Grapevine phenology and climate change: Relationships and trends in the Veneto region of Italy for 1964-2009. *American Journal of Enology and Viticulture, 62*(3), 329-339.

Torregrosa, L., Bigard, A., Doligez, A., Lecourieux, D., Rienth, M., Luchaire, N., Pieri, P., Chatbanyong, R., Shahood, R., Farnos, M., Roux, C., Adiveze, A., Pillet, J., Sire, Y., Zumstein, E., Veyret, M., Le Cunff, L., Lecourieux, F., Saurin, N., Muller, B., Ojeda, H., Houel, C., Péros, J.-P., This, P., Pellegrino, A., & Romieu, C. (2017). Developmental, molecular and genetic studies on grapevine response to temperature open breeding strategies for adaptation to warming. *OENO One, 51*(2), 155-165.

Tonietto, J., & Carbonneau, A. (2004): A Multicriteria Climatic Classification System for Grape-Growing Regions Worldwide. *Agricultural and Forest Meteorology, 124*, 81-97.

Verdugo-Vásquez, N., Pañitrur-De la Fuente, C., & Ortega-Farías, S. (2017). Model development to predict phenological scales of table grapes (cvs. Thompson, Crimson and Superior Seedless and Red Globe) using growing degree days. *OENO One, 51* (3), 277-288.

White, M.A., Diffenbaugh, N.S., Jones, G.V., Pal, J.S., & Giorgi, F. (2006). Extreme heat reduces and shifts United States premium wine production in the 21st century. *Proc Natl Acad Sci USA 103*, 11217–11222.

Winkler, A.J., Cook, A., Kliewer, W.M., & Lider, I.A. (1974). *General Viticulture.* University of California Press, Berkeley.

Zapata, D., Salazar-Gutierrez, M.R., Chaves, B., Keller, M., & Hoogenboom, G. (2016). Predicting Key Phenological Stages for 17 Grapevine Cultivars (*Vitis vinifera* L.). *American Journal of Enology and Viticulture 68,* 60-72.

Zyprian, E., Eibach, R., Trapp, O., Schwander, F., & Töpfer, R. (2018). Grapevine breeding under climate change: Applicability of a molecular marker linked to véraison. *Vitis 57*, 119–123.

***Vitis International Variety Catalogue (2012). Retrieved 2018 December 22, from http://www.vivc.de./