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STUDY ON THE IMPACT OF CLIMATE CHANGES ON THE PHENOLOGY AND ADAPTABILITY OF SOME VARIETIES INTENDED TO PRODUCTION QUALITY RED WINES

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Abstract

If until two or three decades ago, the limit of cultivation of varieties for red wines was located mainly in the regions of the southern half of our country, and only insularly in a few northern areas, as a result of the increase in thermal resources and solar radiation, this has expanded considerably, at the level of the entire country at the level of the entire country. In the medium term, the choice of varieties for red wines, when establishing new plantations in the north of the country, and not only, can be made from the existing international assortment, already tested, from the local Viticultural germplasm, but in the long term the main solution is to cultivate the varieties new, created to better cope with climate change. The present paper aimed to follow the behavior of Cabernet cubin, Cabernet dorio and Cabernet dorsa varieties, not cultivated on a large scale so far in our country. The results showed that they have high biological resistance to frost and cryptogamic diseases, a good choice in the current climate context.

Key words: *adaptation, climate change, grapevine, genetic variability.*

INTRODUCTION

According to the forecasts of the Intergovernmental Panel on Climate Change (IPCC, 2014), the average global temperature on the Earth's surface could increase in this century by 1.8-4.0°C. In this context, it is important to apply innovative measures to mitigate and combat the negative effects of climate change.

Grapevine is one of the plants most affected by these changes, being subjected more and more to radiation, thermal and water stress, with negative effects on production and especially on its quality.

The studies carried out so far have highlighted in most of the country's vineyards a significant warming, with influence on the unfolding of the vine phenophases, the main physiological processes, vegetative growth, grape production and quality (Irimia et al., 2015; Bucur & Babeș, 2016; Bucur & Dejeu, 2017). Also, it was noticed an increase tendency of the average of daily average temperatures, of the average of daily maximum and minimum temperatures, especially during midwinter; this may increase the deacclimation risk of the grapevine and its vulnerability to the frost that may occur subsequently (Cichi et al., 2021).

Heat waves negatively affect the ripening of grapes, with very high accumulation of sugars, the pronounced degradation of acidity (under 6 g/L tartaric acid), the increase of pH values, the development of atypical aromatic compounds, and it also affects the phenolic maturity (Bucur et al., 2019). Consequently, the resulting wines are less suitable for aging, they have a modified aromatic profile and a weaker color. The high concentration of sugars in the berries is not due to photosynthesis and their translocation from the leaves and woody parts of the plant, but due to concentration as a result of water loss through evapotranspiration (Keller, 2015).

To mitigate the negative effects, viticulture benefits from a series of innovative measures to delay the ripening of the grapes and obtain balanced wines with a medium alcohol content, namely: short-term measures - soil maintenance (Dhanush & Patil, 2020; Buesa et al., 2021), management of the green parts of the plant (Silvestroni et al., 2019; Bucur, 2021), choosing the time of harvest and winemaking techniques; medium-term - orientation of the rows, the choice of land for planting, the use of suitable cultivars and rootstocks (Carvalho et al., 2020), and in the long term - the use of irrigation's, even late ones, obtaining new cultivars more adapted to these conditions (Caccavello et al., 2019; Miras-Avalos & Araujo, 2021).

In addition to the negative effects, the variability of the climate has also generated positive effects (the northward expansion of grapevine culture, at higher altitudes).

Comparatively analyzing the evolution and spatial distribution of the oenoclimate aptitude index (IAOe, Teodorescu et al., 1987), in the period 1961-1990, respectively 1991-2013, Irimia et al. (2017), observed that the areas cultivated with varieties for red wine they expanded in the northern part (Moldova), in the west of the country and the Black Sea coast (Figure 1). As a result of this, in recent years, red wine grape varieties have been introduced in the northern regions, while in the southern regions, the composition of the grapes of the same varieties has experienced excessive levels of sugar and lower acidity.

Today, more than ever, global warming is forcing grapevine adaptation strategies in most, if not all, vineyards in the world (Duchêne et al., 2010; Duchêne, 2016; De Cortázar-Atauri et al., 2017), leading to the changing of the maps of wine regions, and these changes will determine a greater attention directed to the establishment of new plantations.

Practically, in wine-growing areas where drought is more severe, the choice of suitable varieties is a priority, being a battle front against the impact of climate change, but it also ensures the reduction of the inputs necessary for the management of the plantation throughout its life cycle.

This choice can be made either by testing already existing varieties both from the existing international assortment, but also from the local viticultural germplasm (Dobrei et al., 2015; Dinu et al., 2021). In recent years, priority has been given to grape varieties for red wines, which gain in quality, the high heliothermal resources recorded and the relative drought being favorable to them. In other words, the genotype influences the phenology of the plants, and different cultivars of grapevine can have a significantly different length of the vegetative cycle depending on the area (Rustioni et al., 2014a; 2014b; Maghradze et al., 2012, Maghradze et al., 2015).

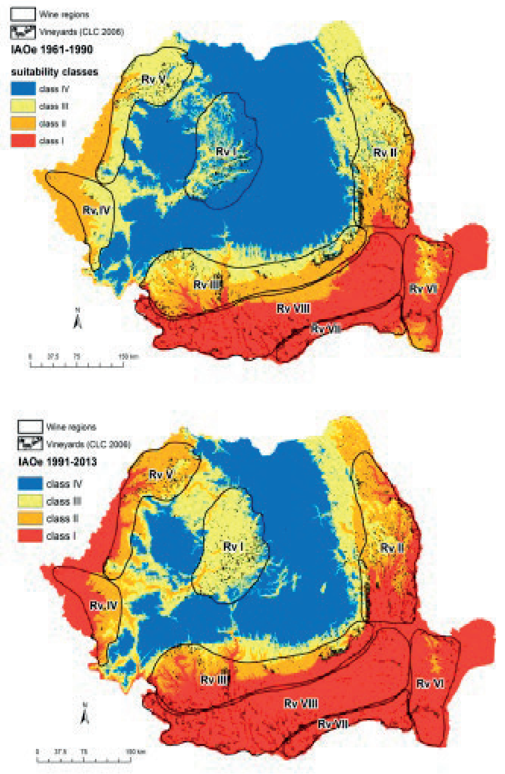

Figure 1. The evolution and spatial distribution of the oenoclimate aptitude index (IAOe), in the period 1961-1990, respectively 1991-2013 (Irimia et al., 2017)

The diversity of vine varieties is an important resource for adapting to climate change (Destrac-Irvine et al., 2020; Antolin et al., 2021).

For this study three table wine red varieties were selected: Cabernet cubin, Cabernet dorio and Cabernet dorsa which are located in the experimental field of the ampelographic collection from the Research and Development Station for Viticulture and Oenology Pietroasa - University of Agronomic Sciences and Veterinary Medicine of Bucharest, an important center for the conservation of the genetic diversity of grapevine and source of Viticultural germplasm, registered in the International Catalog of Ampelographic Collections, under the code indicator "ROM

13", with the right to international exchange of genetic material. These cultivars are not cultivated on a large scale in our country so far and are found only in ampelographic collections, but the current context, of globalization and global warming, determines the monitoring of their agrobiological and technological behavior, and those that prove to be very valuable and that easily adapt to the ecopedoclimatic conditions are to then be cultivated on a larger scale (Stroe, 2020).

MATERIALS AND METHODS

Study area and grapevine cultivars

The research was carried out in the 2019 and 2020 seasons at the University of Agronomic Sciences and Veterinary Medicine Bucharest (N Lat.: 44°47'07"; E Long.: 26°07'28"; alt. 87 m), in the experimental vineyard, on Cabernet cubin, Cabernet dorio and Cabernet dorsa varieties, with the Cabernet Sauvignon - control (C) (Table 1).

The plantation is located on a relatively flat land, and the varieties studied were planted in 2013 at a distance by 2.2 m (inter-row) and 1.2 m (intra-row), with a density of 3787 plant ha^{-1}. The type of pruning applied is double Guyot on the half-stem, and the load distributed on the plant was 30 buds/vine.

During the vegetation period, the shoots were manually directed vertically, and in the last days of July a slight shortening of the shoots was carried out, leaving a canopy height of approximately 1.3 m. The vine was managed without irrigation and a standard disease control program was applied to control downy mildew, powdery mildew and gray rot (*Botrytis*).

Short presentation of Cabernet cubin variety

Is a new variety obtained in 1970 by crossing Blaufränkisch x Cabernet Sauvignon (https://www.wine-searcher.com/ grape-1216-cabernet-cubin), whit late ripening, variety number VIVC - 20004 (Maul & Röckel, 2015). This variety has strong tannic characteristics and rich in flavors berry like Cabernet Sauvignon, and good frost resistance and is suitable for cultivation in regions prone to colder temperatures, but has also been shown to be resistant to oidium, gray rot - like the parent variety Burgund mare (synonymous Blaufränkisch). It is practically the only one of the three analyzed varieties that confirmed its parentage through genetic markers.

Short presentation of Cabernet dorio variety

Is a new red wine variety from Germany, established in 1971 in the cross section of the Blaufränkisch x Dornfelder variety area, Research Institute for Viticulture and Fruit Growing in Weinsberg (Württemberg), (https://www.wine-searcher .com/grape-1217-cabernet-dorio), variety num-ber VIVC - 20003 (Maul & Röckel, 2015). The variety shows great vigor, medium to late ripening and good resistance to low winter temperatures. It produces a velvety red wine with subtly pronounced tannins. It is widely grown in Germany and Switzerland, where the variety raises problems in some years due to its rather late full ripening.

Short presentation of Cabernet dorio variety

Cabernet dorsa is a grape variety for red wines grown in cold climate wine-growing areas (Germany, Belgium, Switzerland), having special performances in Germany and Switzerland. It was obtained in 1971 at the National Institute for Education and Research for Agriculture Weinsberg in Württemberg, by crossing Dornfelder x Cabernet Sauvignon varieties, and since 2003 the variety has received variety protection and has become widespread in culture (https://www.wine-searcher.com/grape-1218-cabernet-dorsa), variety number VIVC - 20002. However, the variety was confirmed with genetic markers as being descended from the crossing of the varieties Blauer Limberger (synonymous Blaufränkisch) x Dornfelder (Maul & Röckel, 2015). It is a medium vigor growth variety with a short growing season of less than 160 days, which ripens its wood well in autumn and shows good resistance to low temperatures over winter. Due to its high sensitivity to powdery mildew, this variety should not be planted in areas where climatic and orographic conditions favor the occurrence of this disease. The wines are rich in tannin, have a cherry flavor and are considered suitable for aging in oak barrels. Due to the dark red color of the wine, it is often used in blends. In 2012 in Germany there were 252 hectares cultivated with Cabernet dorsa, and the trend was increasing.

Table 1. Grape varieties for red wine studied (Bucharest, 2019-2020)

Crt. no.	Cultivar	VIVC* no	Genitors	Color of berry skin
1	Cabernet cubin	20004	Blaufränkisch x Cabernet Sauvignon	blue black
2	Cabernet dorio	20003	Dornfelder x Cabernet Sauvignon**	blue black
3	Cabernet dorsa	20002	Dornfelder x Cabernet Sauvignon**	blue black
4	Cabernet Sauvignon (C)	1929	Cabernet franc x Sauvignon	blue black

*Vitis International Variety Catalogue; **Confirmed by markers: Blaufränkisch x Dornfelder (Maul et al., 2012)

Climatic conditions

For this study, there were used weather data recorded at Bucharest-Băneasa meteorological station for the experimental period (2019-2020), as compared to the reference period (1981 - 2010). A series of climatic data were studied (Table 2), and monthly average temperatures were used to evaluate a set of bioclimatic indices commonly used in viticulture: Huglin index (HI), Winkler index (WI) and cool night index (CNI).

Phenological data

Phenology dates referenced to the stages budburst, flowering, veraison and harvesting maturity, were followed according to BBCH (Bioligische Bundesansalt und Chemische Industrie), modified under the COST Action FA1003 "East-West Collaboration for Grapevine Diversity Exploration and Mobilization of Adaptive Traits for Breeding" (Rustioni et al., 2014). Data were recorded at which 50% of buds, flowers, grapes reached the respective phenological stages (BBCH 008 - budburst; BBCH 605 - flowering; BBCH 801 - veraison and BBCH 809 - berries ripe for harvest). Phenological information was reported for the period 2019-2020 and was expressed as "day of year" (DOY), as the number of days after 1 January.

During the vegetation period, determinations were made on the basis of which the fertility coefficients (absolute, relative) and productivity indices (absolute and relative) were calculated.

Quantitative and qualitative parameters examine in research

The grapes were harvested during the two years of observations between September 6-8. At harvesting, determinations were made on quantitative (bunch weight - g, yield - kg/vine) and qualitative parameters (sugar content - g/L, titratable acidity - g/L tartaric acid, pH, must density - g/cm^3). Sugar concentration in grapes was measured by using an Atago digital refractometer and results were expressed in g/L. Titratable acidity was determined by titrating with 0.1 N NaOH using an Pellet digital biurette, and expresed as g/L tartaric acid.

RESULTS AND DISCUSSIONS

Climatic conditions

The climatic indicators were determined for experimental period (2019-2020) comparativevely with reference period (1981-2010) after the recommendations of National Meteorological Administration (Dima et al., 2019). Table 2 shows a warming during the experimentation period, both during the growing season and also in the summer season. Thus, the largest differences are found in the case of maximum annual temperatures (2.3°C), those during the summer (June-August) (1.4°C) and those average annual temperatures (1.3°C). Other climatic parameters which recorded higher values, compared to the reference period (1981-2010), are average temperature in the growing season (IV-X), which increased by 0.42°C and average annual minimum temperature, which registered an increase of 1.4°C.

Both annual total precipitation and the one in the growing season had a small variation. Practically there was a decrease in annual rainfall, with 40 mm, but there was a slight increase in precipitation in the summer season.

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 129 units for the Huglin index; an increase of 90 units for the Winkler index; an increase of 0.92°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 which 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 table wines. A similar evolution for the CI which 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.

Table 2. The main climatic parameters and bioclimatic indices during the experimentation period (2019-2020) compared to the reference period (1981-2010)

Climatic parameters and bioclimatic indices	Average	Years		Average
	1981-2010	2019	2020	2019-2020
Average annual temperature, ºC	11.55	12.92	12.77	12.85
Average temperature in the growing season (IV-X), ºC	18.07	18.53	18.44	18.49
Average temperature in summer (VI-VIII), ºC	22.50	23.05	22.54	22.80
Average annual minimum temperature, ºC	5.03	6.57	6.27	6.42
Average annual maximum temperature, ºC	17.05	19.28	19.35	19.32
Average maximum temperature in the warmest month, ºC	29.87	29.64	31.06	30.35
Average maximum temperature in summer (VI-VIII), ºC	29.01	30.5	30.38	30.44
Annual total precipitation, mm	608	529	608	569
Total precipitation in the growing season (IV-X), mm	428	385	482	433
Total precipitation in summer (VI-VIII), mm	198	142	292	217
Huglin index (HI)	2346	2458	2492	2475
Winkler index (WI)	1726	1825	1806	1816
Cool night index (CNI)	10.45	10.60	12.13	11.37

The development of the main phenophases

The first effect of temperature rising 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.

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 2019 and 2020.

The time of **budbreak** occured on average 109 DOY (April 18), earlier for Cabernet dorio (106) and later for Cabernet cubin (110) and Cabernet dorsa varieties (111). Considering year-to-year variability in budburst, Cabernet dorio exhibited the lowest variability (SD ± 2.14 days) while Cabernet dorsa has the greatest variation (SD ± 5.66 days).

All three varieties have budburst earlier than the control Cabernet Sauvignon (115 DOY, April 24).

Flowering occurred on average at DOY 150 (May 29), earlier for Cabernet cubin (149) and later for Cabernet dorio (152), the differences between the varieties studied and control Cabernet Sauvignon being relatively small. Cabernet dorio exhibited the least year-to-year variation (SD ± 6.36 days) while Cabernet cubin had a highest year-to-year variation (SD ± 12.02 days).

Veraison was registered on average at DOY 214 (August 01) earlier for Cabernet dorio variety (213) and later for Cabernet cubin and Cabernet dorsa varieties (215). Cabernet cubin and dorio had the lowest year-to-year variation of ± 3.54 days while Cabernet dorsa varied by ±4.95 days during 2019-2020.

The average day of the year for **grapes ripening**, for the 2 studied years, was DOY 246 (September 02), with very small differences for between the three varieties (01-03 of September). Cabernet dorio and dorsa exhibited the lowest year-to-year variability (SD ± 4.95 days) and the highest was recorded by the Cabernet cubin variety (SD ± 6.36 days) and Cabernet sauvignon control variety (SD ± 9.19 days). The results concerning the main pheno-logical timing across the growing season shown that there are not always strong relationships between growth events.

Fertility and productivity determinations

Fertility is the ability of varieties to form fruiting organs and is influenced by the variety, the environmental conditions (climate and soil) in which the variety is grown, and the applied technology. According to the values taken by the fertility coefficients (absolute and relative), the varieties studied were distinguished by a medium fertility, falling into the 1.1-2.0 variation class. The highest value was achieved by the Cabernet cubin variety (Fca = 1.94, Fcr = 1.44), followed by Cabernet dorio and Cabernet dorsa (Table 4). All the varieties analyzed recorded higher values than the Cabernet Sauvignon variety (control), both regarding the absolute and the relative fertility coefficient. In terms of productivity (the amount of grapes in grams or kilograms produced per shoot), the Cabernet dorio and Cabernet cubin varieties were the most productive, with an absolute productivity index of 364.77 g/shoot and 318.16 g/shoot, respectively; the last place being occupied by Cabernet dorsa, with 217.6 g/shoot.

The values place the first two varieties in the class of those with high productivity, and Cabernet dorsa belongs to the group of varieties with medium productivity (Pia between 100-300 g). The value of productivity indices is influenced by the variability of annual environmental conditions, as well as by some agrotechnical measures.

The determinations regarding the quality of the raw material for winemaking

Table 4 also shows determinations regarding the quality of the must, for the 3 new red grape varieties, respectively sugar content, acidity, pH and must density.

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 Cabernet cubin, Cabernet dorio and Cabernet dorsa varieties (2019-2020)

Varieties	Budburst date (DOY)		Flowering date (DOY)		Veraison date (DOY)		Harvest maturity date (DOY)	
	Mean	± SD	Mean	± SD	Mean	± SD	Mean	± SD
Cabernet cubin	110 (April 19)	2.83	149 (May 28)	12.02	215 (August 2)	3.54	247 (September 3)	6.36
Cabernet dorio	106 (April 15)	2.14	152 (May 31)	6.36	213 (July 31)	3.54	246 (September 2)	4.95
Cabernet dorsa	111 (April 20)	5.66	150 (May 29)	10.61	215 (August 2)	4.95	246 (September 2)	4.95
Mean varieties	109 (April 18)		150 (May 29)		214 (August 1)		246 (September 2)	
Cabernet Sauvignon (C)	115 (April 25)	3.54	151 (May 30)	8.48	217 (August 4)	5.66	245 (September 1)	9.19

Table 4. Grapes quantitative and qualitative parameters for varieties analyzed (2019-2020)

Varieties	Fertility coefficient (Fc)		Bunch weight (g)	Productivity indices (Pi)		Yield kg/vine	Sugar content (g/L)	Titratable acidity (g/L tartaric acid)	pH	Must density (g/cm^3)
	absolute	relative		Absolute (g/shoot)	Relative (g/shoot)					
Cabernet cubin	1.94	1.44	164	318.16	236.16	6.26	251	5.7	3.40	1.119
Cabernet dorio	1.86	1.30	193	364.77	250.90	7.51	264	5.0	3.43	1.104
Cabernet dorsa	1.70	1.20	128	217.60	153.60	5.44	295	5.6	4.05	1.095
Cabernet Sauvignon (C)	1.83	1.37	89.5	163.78	122.61	2,149	229	4.2	3.74	1.108

Appreciation of the defining elements of the grape quality of the three analyzed varieties shows that their quantitative and qualitative potential can ensure the obtaining of quality red wines, close to those obtained from their parents, as follows: the Cabernet cubin variety from the parent Cabernet Sauvignon (Stroe & Budescu, 2013), and the Cabernet dorsa and Cabernet Dorio varieties from the Dornfelder and Burgund mare varieties (Stroe & Barcanu-Tudor, 2011). It should be mentioned that, the accumulation of these high amounts of sugars (251 g/L, 264 g/L, 295 g/L) in the context of relatively low acidity (5.7 g/L, 5.0 g/L, 5.6 g/L), is recorded in a fairly favorable area (N Lat.: 44°47'07"; E Long.: 26°07'28"; alt. 87 m), and contextually with the objectives of the study – their

cultivation in somewhat cooler areas, once not suitable for the varieties intended for red wines - as a solution to climate change - they will show a good adaptability. A positive side can be noted in the case of high sugars, as they are a good substrate for the entire metabolism of the plant, being in direct correlation with the accumulation of anthocyanins, at least in the case of the Cabernet cubin cultivar, as a descendant of the Cabernet Sauvignon cultivar, which can have in some years a harvest below the quality standard in terms of the color of the wine obtained. Appreciation of the values involved in ensuring an alcoholic potential (Table 4) demonstrates the obtaining of wines of over 14 v.% alcohol, against the background of sufficient acidity.

CONCLUSIONS

The cultivars Cabernet cubin, Cabernet dorio and Cabernet dorsa have adapted well to the environmental conditions of southern Romania, obtaining good and superior quality productions, but at this stage (research so that it can later be transferred into their cultivation), it cannot be discussed which areas would be more suitable for them or where the possibility of obtaining wines could be appreciated from a qualitative aspect.

As a first step to follow would be to continue the research for several years and taking them into cultivation afterwards, in the beginning on smaller areas, so that later, the results will determine whether it is possible to move to significantly larger areas.

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