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The impact of climate change on the grapevine in the topoclimate of the Murfatlar wine center

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Abstract

Excedentary, deficient or untimely reaching of the optimal thermal, insolation and water thresholds influences the passage of the vegetation phenophases of the varieties, always with negative implications in the quantitative and qualitative grape production.

Our research team conducted studies on the main climatic elements recorded in the Murfatlar wine center during 1989-2018 and created a database on the succession of vegetation phenophases, in relation to climate change and the specificity of wine and table grapevine cultivars, between the years 2000-2019.

Due to climate change, significant effects may be seen on grapevines, due to the interaction between climatic conditions specific to the Murfatlar vineyard, the effect of increased CO_2 on photosynthesis, and the genetic resistance of plants.

The analysis of the climatic elements carried out over a period of 30 years (1989-2018) shows an increase in temperatures during the winter and during the vegetation period, the four seasons being no longer very well defined.

By analyzing the development of the vegetation phenophases in the Murfatlar Wine Center during the 20 studied years, the following can be observed: budburst takes place throughout April for all the studied cultivars; flowering begins in the last decade of May and early June, depending on the cultivar and the recorded temperatures; harvest for the early ripening varieties begins in the second half of July, for the medium ripening varieties in August, and for the late ripening varieties in September; full maturity is usually achieved one month after harvest, depending on the characteristics of each variety; harvesting takes place when the grapes have reached the sugar concentration and acidity necessary to obtain quality wines.

Keywords: temperature, grape varieties, vegetation phenophases, cultivars

1.Introduction

Grapevine is a light and heat loving plant [8,12] of great socio-economic importance, that uses the energy resources offered by the environment rationally and efficiently, but at the same time conditions the dynamics of its growth and development according to how they comply with its vegetation requirements [4,5]. The sudden oscillations of the meteorological elements speed up or slow down the growth and development process of the grapevine generally speaking [10], but the effect is different from one variety to another according to their hereditary vital biorhythms specific to the vegetation phenophases [15].

Excedentary, deficient or untimely reaching of the optimal thermal, insolation and water thresholds influences the passage of the vegetation phenophases of the varieties, always with negative implications in grape production [1]. These climatic factors variations present the disadvantage of altering grape quality, making the full potential of certain varieties unachievable [2].

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Climate change is generally recognized worldwide, therefore it is essential to evaluate its effects, especially in the case of perennial horticultural crops [16]. Nowadays, there is a rising interest regarding the impact of increasing temperatures on the grapevine [3]. Knowledge of the climate, of the annual and multiannual variations and of their deviations from the normal, represents a priority requirement in viticulture [11].

Material and method

Our research team conducted studies on the main climatic elements recorded in the Murfatlar wine center during 1989-2018 and created a database on the succession of vegetation phenophases, in relation to climate change and the specificity of wine and table grapevine cultivars, between the years 2000-2019.

The evolution of the phenological spectrum over time was followed, for the following varieties: Columna, Mamaia, Pinot Gris 13 Mf, Fetească neagră 9 Mf, Chardonnay 25 Mf, Afuz Ali 93 Mf and Aurana, cultivated in the plantations of the research station, in direct correlation with the climatic factors, in the context of climate change and the determination of technological potential.

Results and discussion

The vineyards of the Murfatlar wine center are located on plateaus with beveled banks, with smooth slopes and predominantly southern and south-western exposures. In the southern part of the territory they are crossed by the old Carasu Valley, the current Danube-Black Sea Canal.

The relief is of tabular-structural type, with absolute latitudes of 100-130 m, rarely but deeply fragmented by valleys, with strongly inclined slopes (15º-30º) of the 'cuesta' type (the left slope of the asymmetric Carasu valley) or relatively symmetrical canyon-type, affected by intense slope processes, locally blocked by terracing.

The climate is continental, with hot and dry summers, moderate winters, early springs and late autumns, ideal for ripening and overripening grapes. The surface water network is sparse, with semi-permanent flows and runoff, due to poor precipitation and groundwater supply, rapid infiltration into the permeable lithopedological substrate, and strong evaporation.

The groundwater from the alluvium of the plains and deluvio-colluviums on the slope is shallow (2-5 m), discontinuous in quantity, and those at the base of the loess on the plateaus or in the underlying Sarmatic plate are at great depths (30-50 m), meaning they are hard to reach.

Soils are representative of steppe chernozemic molisols (carbonate chernozems, typical chernozems) on loess substrates, typical and lithic rendzines, regosols and erodisols on strongly degraded natural or anthropozoogenic slopes [14].

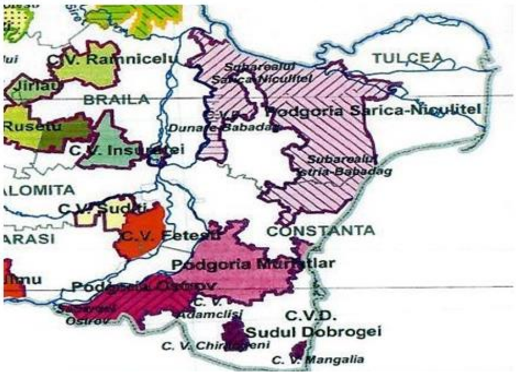

Figure 1. Murfatlar Wine Center, according to [14]

The arid soil, with a limestone support, is beneficial for obtaining quality wines. Murfatlar enjoys prolonged exposure to the sun, a poor rainfall regime, and the influence of the Black Sea, which acts as a thermal regulator. The pedological and agrochemical factors that influence the development of the grapevine are elements that belong to the concept of "terroir", which is defined as "an ensemble of soil and climate corresponding to a certain vineyard, which contributes to the specificity. the wine produced in that territory" [9].

The fame of the vineyard is given especially by the sweet wines, obtained naturally from grapes with a high sugar content, harvested when overripe.

Due to climate change, significant effects may be seen on grapevines, due to the interaction between climatic conditions specific to the Murfatlar vineyard, the effect of increased CO_2 on photosynthesis, and the genetic resistance of plants.

The analysis of the climatic elements carried out over a period of 30 years (1989-2018) shows an increase in temperatures during the winter and during the vegetation period, so the four seasons are no longer very well defined (Tables 1, 2 ,3).

The thermal balance represents the sum of the temperature degrees and can be global, active or useful: the global thermal balance (Σtg, °C) represents the sum of the average daytime temperatures higher than 0ºC during the vegetation period (1.04 - 31.09) - in Romanian vineyards it varies between 2700 and 3600 ºC, the values lower than 2700 ºC being considered restrictive for the vine; the active thermal balance (Σta, °C) represents the sum of the average diurnal temperatures higher than 10 ºC during the vegetation period; in the vineyards of the Dobrogea Hills Wine Region, Σta varies between 3016 and 3296 ºC, compared to the average of 3164, the values lower than 2600 ºC being restrictive for the cultivation of grapevine; the useful thermal balance (Σtu, °C) is calculated by summing the average daytime temperatures higher than 10 ºC, from which the biological threshold of 10 ºC is previously subtracted; In the vineyards of the Dobrogea Hills wine region, Σtu has values between 1396 and 1566 ºC, compared to the average of 1476, the lowest of 1000ºC being restrictive for the cultivation of vines [13].

Table 1. The thermal balance measured in the Murfatlar vineyard in the 1989-1998 period

Climatic elements	1989	1990	1991	1992	1993	1994	1995	1996	1997	1998
Global thermal balance, (Σt°g)	4199,4	3987	4148,7	4035,3	4201,2	4658,7	4482,2	3873,5	4143,3	4769,8
Active thermal balance, (Σt°a)	3375,7	3349,3	3606	3746,3	3858,3	4065,4	3957	3680,8	3759,8	4228,9
Useful thermal balance, (Σt°u)	1745,6	1719,3	1616	1661,7	1840,1	2049,5	1873,3	1800,8	1779,8	2028,8

Table 2. The thermal balance measured in the Murfatlar vineyard in the 1999-2008 period

Climatic elements	1999	2000	2001	2002	2003	2004	2005	2006	2007	2008
Global thermal balance, (Σt°g)	4636,5	4751,1	5123,4	4689,4	4313,4	4527,4	4665,4	4567,1	5362,2	5085,6
Active thermal balance, Σt°a)	4466,6	4274,5	4555,8	4280,4	4132,6	3843,4	4084,5	4208,3	4532,7	4649,4
Useful thermal balance, (Σt°u)	2066,6	2221,5	2145,5	2090,4	2052,6	1636,1	2033,7	2046,9	3570,1	2320,3

Table 3. The thermal balance measured in the Murfatlar vineyard in the 2009-2018 period

Climatic elements	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018
Global thermal balance, (Σt°g)	5291,6	5348,8	4953,8	5075,6	5373,8	5476,0	5500,9	5757,8	5303,8	5379,6
Active thermal balance, Σt°a)	4614,1	5033,1	4509,1	4737,4	4810,0	4938,5	4864,9	5216,1	4826,9	4815,5
Useful thermal balance, (Σt°u)	2364,1	2533,1	2299,1	2527,4	2617,5	2508,5	2600,2	2676,1	2515	2427,2

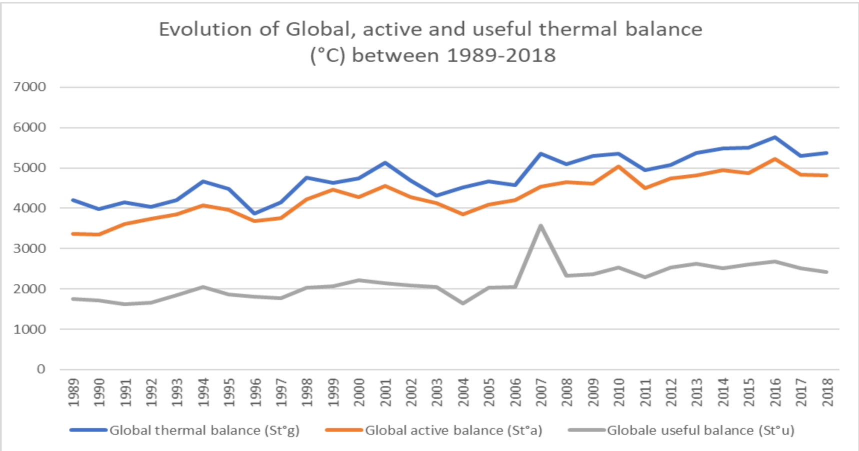

Figure 2. Evolution of global, active si useful thermal balance (°C) between 1989-2018

By analyzing the development of vegetation phenophases in the Murfatlar Wine Center during the 20 studied years (Tables 4 – 7, Figures 3 – 6) the following can be observed:

- Budburst takes place throughout April in all studied varieties;
- Flowering begins in the last decade of May and early June, depending on the variety and recorded temperatures;
- The harvest for the early ripening varieties starts in the second half of July, for the middle ripening ones in August, and for the late ripening ones in September;
- Maturity is usually achieved one month after the harvest, depending on the specifics of each variety.

During the studied period, a shortening of the vegetation phenophases is observed, thus the period from budburst to grape maturity is reduced by 10 to 15 days, and the period between flowering and veraison is shortened by 10 days, due to the climatic changes that also affect the grapevine.

Climatic data are needed for the correct zoning of grapevine cultivars. The start of the vegetation period is conditioned by reaching a thermal value of 8-10 °C in the soil, at the level of the active roots (20-40 cm). The temperature at which budburst begins is 10 °C, higher than in other plant species. The minimum temperature for flower opening is 15 °C, each variety requiring a certain thermal value for its grapes to reach full maturity [7]. The need for thermal resources varies considerably from one variety to another and is closely related to the length of the vegetation period of each cultivar [6].

Table 4. The budburst phenophase over a period of 20 years, for the grapevine varieties cultivated in the Murfatlar viticultural area

Cultivar	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Columna	11-IV	14-IV	22-IV	04-V	18-IV	23-IV	26-IV	23-IV	17-IV	16-IV
Mamaia	12-IV	13-IV	21-IV	29-IV	15-IV	21-IV	26-IV	20-IV	15-IV	20-IV
Pinot Gris 13 Mf	12-IV	15-IV	23-IV	05-V	15-IV	28-IV	22-IV	27-IV	27-IV	20-IV
Fetească neagră 9 Mf	Clone registered in 2009									19-IV
Chardonnay 25 Mf	30-IV	28-IV	22-IV	13-IV	10-IV	14-IV	21-IV	13-IV	17-IV	20-IV
Afuz Ali 93 Mf	12-IV	13-IV	22-IV	30-IV	16-IV	27-IV	27-IV	20-IV	18-IV	20-IV
Cultivar	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Columna	20-IV	22-IV	20-IV	22-IV	23-IV	20-IV	18-IV	22-IV	24-IV	23-IV
Mamaia	19-IV	16-IV	18-IV	20-IV	22-IV	23-IV	16-IV	20-IV	24-IV	26-IV
Pinot Gris 13 Mf	18-IV	26-IV	18-IV	19-IV	23-IV	22-IV	20-IV	20-IV	21-IV	22-IV
Fetească neagră 9 Mf	18-IV	14-IV	16-IV	19-IV	20-IV	21-IV	14-IV	18-IV	21-IV	25-IV
Chardonnay 25 Mf	18-IV	02-V	20-IV	20-IV	12-IV	10-IV	15-IV	20-IV	29-IV	17-IV
Afuz Ali 93 Mf	22-IV	23-IV	21-IV	21-IV	20-IV	17-IV	14-IV	24-IV	26-IV	22-IV
Aurana	Cultivar registered in 2014				16-IV	15-IV	12-IV	17-IV	15-IV	20-IV

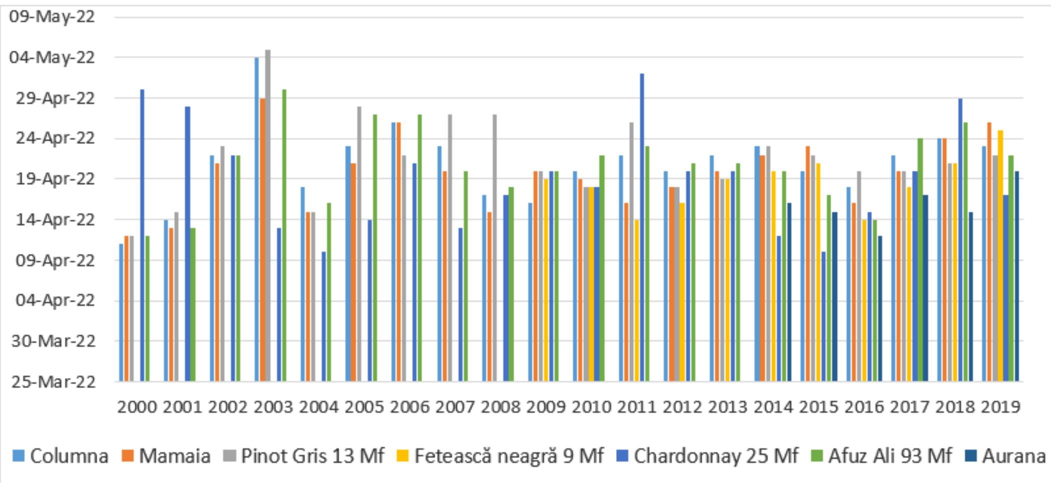

Figure 3. Bud burst phenophase for the studied cultivars, 2000-2019

Table 5. The flowering phenophase over a period of 20 years, for the grapevine varieties cultivated in the Murfatlar

Cultivar	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Columna	21-V	25-V	29-V	12-VI	11-VI	15-VI	8-VI	4-VI	3-VI	5-VI
Mamaia	24-V	26-V	25-V	8-VI	8-VI	13-VI	8-VI	3-VI	6-VI	7-VI
Pinot Gris 13 Mf	28-V	28-V	30-V	13-VI	8-VI	11-VI	12-VI	7-VI	4-VI	2-VI
Fetească neagră 9 Mf	Clone registered in 2009									5-VI
Chardonnay 25 Mf	10-VI	9-VI	2-VI	30-V	24-V	27-V	29-V	12-VI	7-VI	11-VI
Afuz Ali 93 Mf	25-V	26-V	27-V	10-VI	10-VI	10-VI	8-VI	3-VI	7-VI	6-VI
Cultivar	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Columna	7-VI	27-V	26-V	27-V	6-VI	26-V	3-VI	30-V	30-V	29-V
Mamaia	9-VI	26-V	28-V	30-V	10-VI	28-V	30-V	29-V	29-V	4-VI
Pinot Gris 13 Mf	5-VI	10-VI	28-V	24-V	8-VI	5-VI	3-VI	2-VI	28-V	27-V
Fetească neagră 9 Mf	5-VI	28-V	26-V	28-V	3-VI	30-V	29-V	1-VI	28-V	30-V
Chardonnay 25 Mf	6-VI	30-V	12-VI	10-VI	3-VI	31-V	27-V	25-V	27-V	10-VI
Afuz Ali 93 Mf	8-VI	30-V	25-V	31-V	10-VI	10-VI	6-VI	6-VI	2-VI	29-V
Aurana	Cultivar registered in 2014				1-VI	25-V	26-V	30-V	25-V	27-V

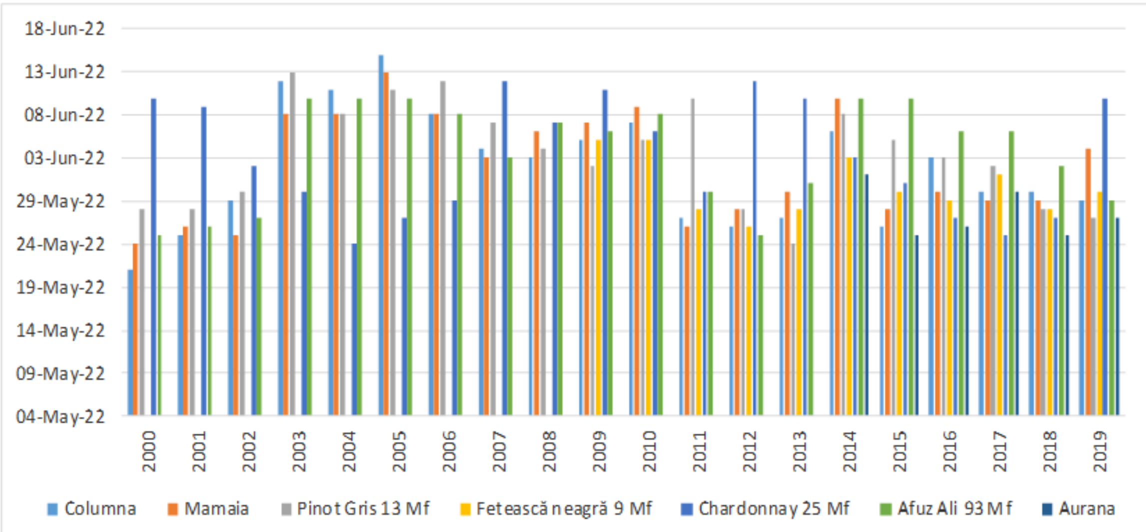

Figure 4. Flowering phenophase for the studied cultivars, 2000-2019

Table 6. The veraison phenophase over a period of 20 years, for the grapevine varieties cultivated in the Murfatlar viticultural area

Cultivar	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Columna	10-VIII	12-VIII	14-VIII	25-VIII	19-VIII	26-VIII	28-VIII	14-VIII	16-VIII	7-VIII
Mamaia	10-VIII	11-VIII	13-VIII	21-VIII	18-VIII	20-VIII	10-VIII	7-VIII	13-VIII	15-VIII
Pinot Gris 13 Mf	12-VIII	13-VIII	15-VIII	26-VIII	14-VIII	20-VIII	17-VIII	27-VIII	8-VIII	10-VIII
Fetească neagră 9 Mf	Clone registered in 2009									14-VIII
Chardonnay 25 Mf	28-VIII	24-VIII	23-VIII	18-VIII	10-VIII	10-VIII	14-VIII	25-VIII	11-VIII	15-VIII
Afuz Ali 93 Mf	11-VIII	12-VIII	16-VIII	23-VIII	19-VIII	21-VIII	16-VIII	13-VIII	19-VIII	14-VIII
Cultivar	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Columna	20-VIII	18-VIII	23-VIII	19-VIII	7-VIII	26-VIII	23-VIII	4-VIII	6-VIII	15-VIII
Mamaia	16-VIII	5-VIII	18-VIII	5-VIII	10-VIII	16-VIII	26-VIII	21-VIII	3-VIII	29-VII
Pinot Gris 13 Mf	20-VIII	20-VIII	26-VII	6-VIII	9-VIII	25-VIII	16-VIII	20-VIII	7-VIII	18-VIII
Fetească neagră 9 Mf	15-VIII	20-VIII	23-VIII	4-VIII	8-VIII	14-VIII	24-VIII	20-VIII	1-VIII	28-VII
Chardonnay 25 Mf	14-VIII	13-VIII	20-VIII	22-VIII	23-VIII	20-VIII	11-VIII	10-VIII	15-VIII	23-VIII
Afuz Ali 93 Mf	15-VIII	28-VIII	3-IX	5-VIII	11-VIII	5-VIII	13-VIII	16-VIII	14-VIII	9-VIII
Aurana	Cultivar registered in 2014				26-VII	28-VII	29-VII	26-VII	24-VII	23-VII

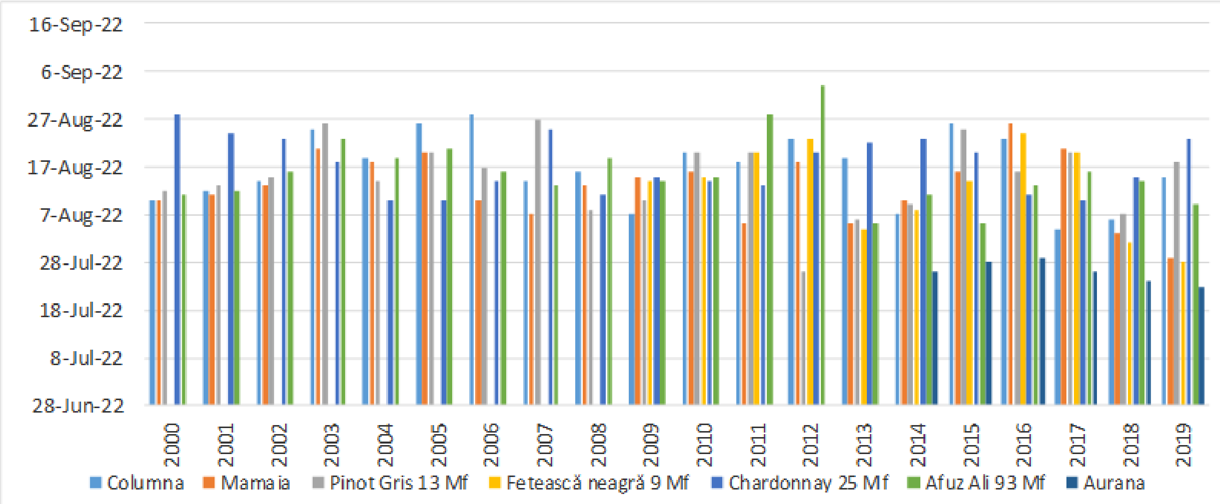

Figure 5. Veraison phenophase for the studied cultivars, 2000-2019

Table 7. Maturity over a period of 20 years, for the grapevine varieties cultivated in the Murfatlar viticultural area

Cultivar	**2000**	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**
Columna	19-IX	16-IX	17-IX	21-IX	16-IX	20-IX	24-IX	21-IX	15-IX	19-IX
Mamaia	13-IX	14-IX	12-IX	17-IX	16-IX	20-IX	18-IX	12-IX	18-IX	25-IX
Pinot Gris 13 Mf	20-IX	17-IX	18-IX	22-IX	13-IX	21-IX	16-IX	20-IX	12-IX	10-IX
Fetească neagră 9 Mf	Clone registered in 2009									20-IX
Chardonnay 25 Mf	17-IX	22-IX	23-IX	19-IX	18-IX	17-IX	16-IX	18-IX	10-IX	15-IX
Afuz Ali 93 Mf	15-IX	16-IX	15-IX	19-IX	16-IX	20-IX	17-IX	13-IX	21-IX	28-IX
Cultivar	**2010**	**2011**	**2012**	**2013**	**2014**	**2015**	**2016**	**2017**	**2018**	**2019**
Columna	23-IX	4-IX	18-IX	19-IX	19-IX	25-IX	23-IX	20-IX	26-IX	12-IX
Mamaia	23-IX	16-IX	10-IX	13-IX	19-IX	15-IX	18-IX	17-IX	24-IX	15-IX
Pinot Gris 13 Mf	21-IX	17-IX	15-IX	17-IX	19-IX	3-IX	28-IX	18-IX	3-IX	27-IX
Fetească neagră 9 Mf	20-IX	24-IX	15-IX	12-IX	14-IX	29-VIII	16-IX	20-IX	10-IX	12-IX
Chardonnay 25 Mf	17-IX	16-IX	20-IX	18-IX	20-IX	21-IX	16-IX	17-IX	21-IX	16-IX
Afuz Ali 93 Mf	30-IX	23-IX	30-IX	26-IX	20-IX	23-IX	21-IX	27-IX	17-IX	28-IX
Aurana	Cultivar registered in 2014				30-VII	3-VIII	5-VIII	1-VIII	28-VII	29-VII

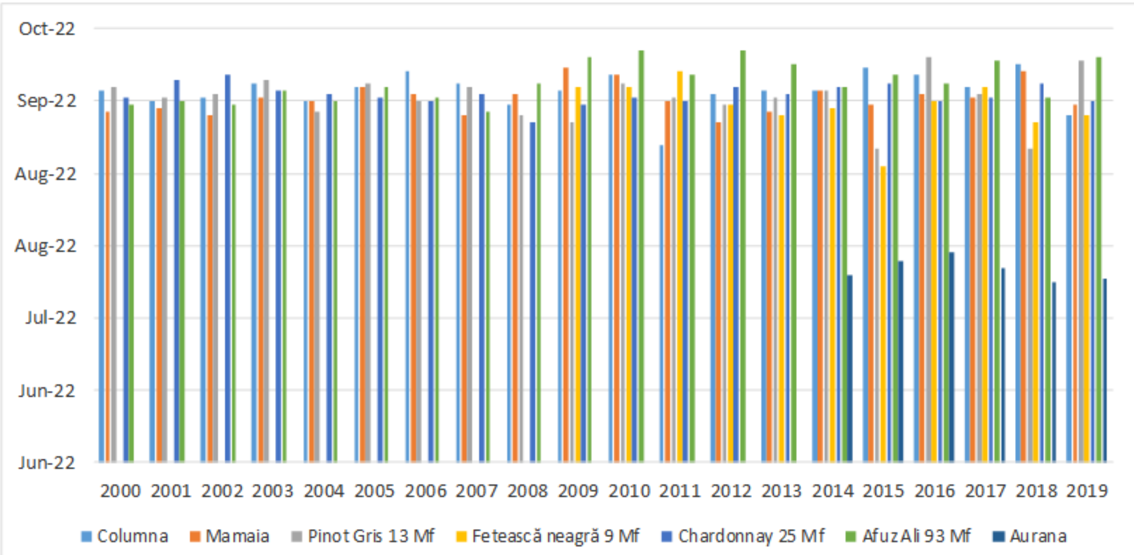

Figure 6. Full maturity for the studied cultivars, 2000-2019

The year 2019 registered values close to or higher than the multiannual average, being a very good year for the grapevine.

The year 2020 was a difficult year for the vineyards, the active and useful thermal balances registering values higher than the multiannual average (Table 8, Figure 7).

Table 8. Synthesis of the main climatic elements of the years 2019 – 2020 compared to multiannual averages

Climatic elements	**Multiannual average**	**2019**	**2020**
Global thermal balance, (Σt°g)	4790,7	5058,6	4999,6
Active thermal balance, Σt°a)	4300,7	4134	4500,5
Useful thermal balance, (Σt°u)	2178,9	2354	2270,5

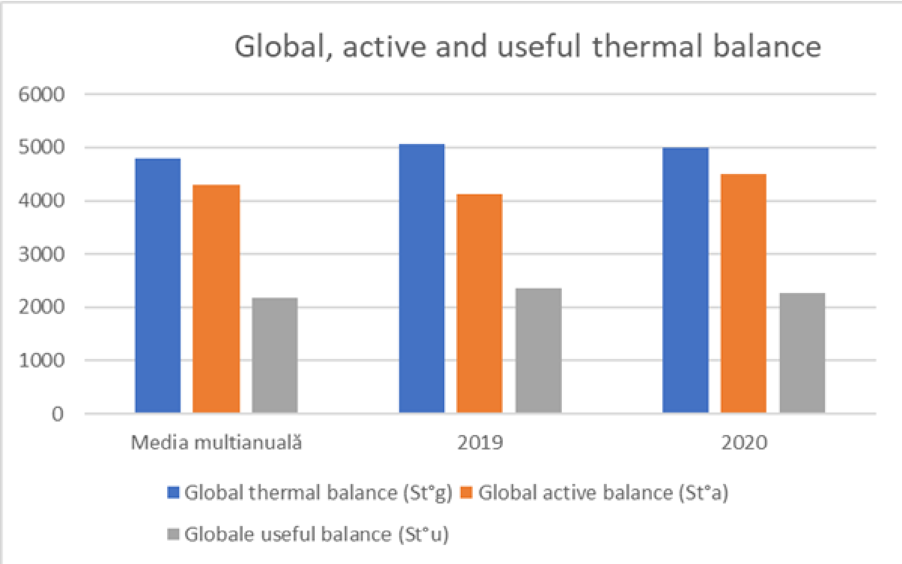

Figure 7. Global, active and useful thermal balance

Conclusion

- The vineyards of the Murfatlar wine center are located on plateaus with beveled banks, slopes with smooth slopes and predominantly southern and south-western exposures. In the southern part of the territory they are crossed by the old Carasu Valley, the current Danube-Black Sea Canal.
- The climate is continental, with hot and dry summers, moderate winters, early springs and late autumns, ideal for ripening and overripening grapes.
- Soils are representative of steppe chernozemic molisols (carbonate chernozems, typical chernozems) on loess substrates.
- Murfatlar is characterized by prolonged sun exposure, a poor rainfall regime, and the influence of the Black Sea, which acts as a thermal regulator.
- The fame of the vineyard is given especially by the sweet wines, obtained naturally from grapes with a high sugar content, harvested when overripe.
- Climate change may have significant effects on the grapevine due to the interaction between climatic conditions specific to Murfatlar vineyard, the effect of increased CO_2 on photosynthesis and plant genetic resistance.
- The analysis of the climatic elements carried out over a period of 30 years (1989-2018) shows an increase in temperatures during the winter and during the vegetation period, the four seasons being no longer very well defined.
- In the studied period there is a shortening of the vegetation phenophases, so the period from budburst to grape ripening is reduced by 10-15 days, and from flowering to veraison by 10 days, due to climate change that also affects the grapevine
- The year 2020 was a difficult year for the vineyards, because the active and useful thermal balances had values higher than the multiannual average.

Compliance with Ethics Requirements. Authors declare that they respect the journal's ethics requirements. Authors declare that they have no conflict of interest and all procedures involving human or animal subjects (if exist) respect the specific regulation and standards.

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