EXTREME CLIMATIC PHENOMENA AND THEIR INFLUENCE ON THE STRUCTURE OF WINE GRAPES IN MINIS-MADERAT VINEYARD

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Abstract. *The most frequent extreme climatic phenomena in the Minis-Maderat Vineyard are hail and drought. In the last 10 years, the period of extreme drought has increased from 2-3 to over 7 weeks, in the months of June-July-August, when the grapevine has the greatest need for water, in the phenophases of berry growth, bunch compaction and véraison. The mechanical analysis of the grapes for wine grape varieties from Podgoria Miniş-Măderat reveals this aspect in the composition of their structure.*

Keywords*: climate, extreme climatic, Miniş-Măderat, grapevine, water, structure*

INTRODUCTION

The purpose of this research is to determine and observe the impact of extreme drought on the development of grapevines in the Ghioroc area of the Minis-Maderat Vineyard. During the vegetation period, the months of June-July-August, the grapevine goes through several phenophases of vegetation, which mark the processes of growth, development and reproduction.

The mechanisms involved in sugar import and compartmentation into the wine grape berries has been studied in order to show how high-temperatures affect berry set and development and alter the normal sugar content of the fruit. Also, the research demonstrates thet the peaks of high temperature, nowadays more and more frequent, may stop the ripening progress. (Norronha, 2010) Beginning near the onset of veraison, sugar concentration increases rapidly, and may reach 25 percent or more of berry fresh weight by the time of harvest. (Dokoozlian, 2022).

With the development of the wine grape berry, the transverse diameter, longitudinal diameter, and single-berry weight continued to increase (Zhang, 2021). However, the anatomy of the central vasculature in the grape berry has not been yet well-described, and this is considered a consequence of the challenging location of this tissue (Xiao et all, 2021).

The incidence of long periods of drought, with temperatures reaching over 40^{o}C, is becoming more present every year and with an alarming frequency. In the Minis-Maderat Vineyard, the changes have become more and more visible in the last 10 years. According to the Huglin index calculated for this Romanian viticultural area (Heizer, 2021) that reached the value of 2467, which means being in the warm-temperate climate, such as Napa (USA) (Jones et all, 2010), Northwestern Spain (Piña-Rey et all, 2020) or Montpellier (France) (Laget et all, 2008), these periods of extreme drought greatly influence the quality and quantity of grape production for wine.

Combined with regional climate scenarios, analyzing the spatial variability of local climate (bioclimatic index and phenologic modelling) makes it possible to refine the models' spatial resolution and to propose rational adaptation methods at the vineyard scale rather than at the level of major wine regions (Le Roux et all, 2020). Only a few researches have been done on the structure of *Mustoasa de Maderat* grapevine variety (Mihalca and Oana, 1987) and on the characteristics (Niculaua, 2010), because until 2011, when it was included as a valuable variety in the PDO Minis – Romania (ONVPV, 2017), it does not seem to have aroused interest for research or for the wine industry. On the other hand, several scientific materials and articles have been written about *Feteasca regala*, the most recent one being a comparison of the parameters of the grapevine variety made on wines produced in three wine-growing regions of Romania, but not for the Minis-Maderat vineyard (Stegarus et all, 2021).

MATERIAL AND METHODS

The research methodology was based on quantitative research methods, where numbers were used to measure variables, ensuring the verification of some connections between the climatic factor and the researched element - the wine grape berry and between the objective of interest in the research (mechanical analysis of grapes, corroboration with weather data related to the studied period and phenophase) and qualitative research methods (focusing on variables, comparative analysis of data resulting from quantitative research)

The chosen research methods determined specific work techniques. The working techniques in research represent the operational manner of the approaches to the phenomena, the events subject to the research. The same method is subordinated to several techniques. Each technique can be applied in different ways. In this research, the level of management of the elements on which the progress of grapes ripening depends, according to the known climatic elements, was used.

The climatic data were taken from the meteorological station of the Minis Research and Development Station for Viticulture and Winemaking, located in Arad county, Romania, at the coordinates: latitude N46°9'32", longitude E21°35'43" with an altitude of 185 m, at the Zarand Mountains foot slope. The station records, stores and automatically transmits to a central computing unit: air temperature, direction and intensity of air currents, humidity, atmospheric pressure and amount of precipitation.

Two varieties of white wine grapes representative for the Minis-Maderat Vineyard were chosen: *Feteasca regala* and *Mustoasa de Maderat*. The determinations were made between 26.08.2022 – 05.09.2022, on grapes from the SCDVV Minis plantation, in the area of the Ghioroc township. The plantation was established in 1998, the vine is managed in a semi-tall form, with a density of 3,745 vine plants/ha (gaps appeared during the exploitation of the plantation, the initial density being 4,545 vine plants/ha), and prunning type is double Guyot. The maintenance work was carried out according to the technology, and the analyzed grapes showed no traces of infections caused by cryptogamic diseases. The vineyard benefits from predominantly southern exposure. The microclimate has Mediterranean influences, which materializes through long, warm and dry autumns. Ecoclimatic data: average annual temperature 11.2ºC, sum of annual precipitation 626 mm (of which 410 mm in the growing season), sum of active temperatures 3,291ºC, sum of sunshine hours 1,490 and sum of active precipitation 365 mm. The relative humidity of the air is about 75%, the average over 10 years.

The bio-climatic factors that influenced over time the quality of grapes from Minis - Maderat Vineyard: the drought of 1862, 1863, 1865, 1873, 1879, 1883, 1884, 1888, 1891, 1895, 1898, 1902, 1906, 1907-1908 , 1917-1918, 1923-1924, 1927-1928, 1934-1935, 1945-1950, 1982-1983, 1985-1986, 1987-1988, 1992-1993, 1999-2002, 2005, 2009, 2011; the very high summers heats of 1851, 1879, 1905, 1906, 2009; the noble rot [*Botrytis cinerea*, f.c. *Botryotinia fuckeliana* (de Bary)] attack: 1872, 1879, 1882, 1895, 1906, 2005, 2011.

The weighing method was used to determine the following parameters: grape clusters weight and volume, mass of 100 berries, weight of berries and rachis, average weight of a berry, pulp, skin and seeds.

For the quantitative determinations, the Class 4 Balance, Type - MB-C-03, Accuracy II - year of manufacture 1980 was used, with the use of counterweights from the working kit of this balance (Analytical weights kit type - MIG "Termotehnica" - manufacture year 1959), stainless steel pincers for extracting seeds, Petri dishes of different sizes for collecting seeds, Berzelius beakers for collecting the liquid and semi-solid fraction, graduated cylinder of 500 ml, 1 L and 1.5 L, for measuring the volume of the bunch with and without berries (rachis).

The tool represents the materialization of a method. The following tools were used to materialize the quantitative and qualitative research methods: the weather station report, the tables, the graphic representation and the comparative analysis.

RESULTS AND DISCUSSIONS

The result of the research ensures a validation of the hypothesis or hypotheses by recommending a course of action. Drought resistance is assessed in the critical phases of the plants (shoot growth, flowering, fruit onset and berries growth, bunches compaction, veraison), by assigning grades (0-9) according to the changes that the plants undergo under the action of drought: the general appearance of grapevine plants; the changes in the leaves color; wilting speed; the percentage of sterility (milleting or/and beading), the number of dead vine plants and a lot of other physiological changes.

Useful water for plants (Corman et all, 2015) is classified in:

 Water very easily accessible to plants - the humidity range from CT (total water holding capacity in the soil) to CC (field capacity) (gravitational water, it moves under the influence of gravitational forces and is not retained in the soil for a long time). Excess gravity water reduces soil aeration and negatively influences the root system of grapevine plants.

 Easily and moderately accessible water for plants - the range of soil moisture from CC to URC (moisture breaking the continuity of water in the soil capillaries) (capillary water, moves under the influence of capillary forces and is retained in the soil for a long time, forming the most important reserves of useful moisture for grapevine growth).

 Water that is difficult for plants to access - the moisture range from URC to CO (withering coefficient) (film water, moves under the influence of sorption forces around the molecules of the colloidal micelle of the soil and is retained in the soil for a long time. It has an influence weaker in bunches formation, but extremely important in the survival of the plantation.

The grapevine is part of the heliophilous and thermophilic plants, but it is far from being classified as xerophytes. Therefore, long periods of drought, alternating with extreme drought (when the wilting capacity index - CO is exceeded) are not favorable for its vegetation. As a plant that does not reproduce predominantly by seed, it will save resources by sacrificing the fruit set. For the grapevines, the range of accessibility for soil water

utilization must be between CC and URC. This range came extremely close to, and in some places even exceeded CO, during the periods in Table 1.

The longest period without any precipitation was between: 27 June 2022 – 25 July 2022, followed by a single day with 22 mm of rain, after which the drought set in again, between 1 – 7 August 2022. Rainfall in August they were sporadic, with intervals of a few days between them, the amounts of rainwater falling being insufficient to penetrate more than 2-3 cm into the soil deep, from where they quickly evaporated, under the influence of high temperatures in the air.

Table 1. The period and amount of precipitation 2022

Month	Week	Interval days	Amount (mm) of precipitation
June	22	30.05 - 05.06	17
	23	06.06 - 12.06	9.7
	24	13.06 - 19.06	0.4
	25	20.06 - 26.06	4
	26	27.06 - 03.07	0
July	27	04.07 - 10.07	0
	28	11.07 - 17.07	0
	29	18.07 - 24.07	0
	30	25.07 - 31.07	22
	31	01.08 - 07.08	0
August	32	08.08 - 14.08	34.4
	33	15.08 - 21.08	24
	34	22.08 - 28.08	14.8
	35	29.08 - 04.09	82.2

Table 2. The period of extreme drought 2022

Month	**Week**	**Interval days**	**Average Temp. (°C)**	**Absolutely minimum air temperature °C**	**Absolutely maximum air temperature °C**
June	22	30.05 - 05.06	22.0	13	32.5
	23	06.06 - 12.06	23.6	12.7	31.8
	24	13.06 - 19.06	22.7	10.9	32.9
	25	20.06 - 26.06	24.3	10.6	33.7
July	26	27.06 - 03.07	29.9	19.6	39.3
	27	04.07 - 10.07	24.7	13.5	38.4
	28	11.07 - 17.07	22.8	**9.2***	35.8
	29	18.07 - 24.07	26.7	12.3	**41.4****
	30	25.07 - 31.07	26.1	15.5	38.5
	31	01.08 - 07.08	25.5	14.2	38.6
August	32	08.08 - 14.08	24.2	14	34.4
	33	15.08 - 21.08	27.1	18.8	38.8
	34	22.08 - 28.08	24.7	16.7	35.8
	35	29.08 - 04.09	20.7	13.3	32.4

The absolute minimum temperature was recorded between July 11 and 17, 2022, with a value of 9.2^{o}C* (Table 2). The absolute maximum was recorded between 18 and 24 July 2022, amounting to 41.4^{o}C**(Table 2).

Figures 1, 2 and 3 show the differences between the monthly temperatures and the multiannual averages of each month, June-July-August 2022, in the Ghioroc area.

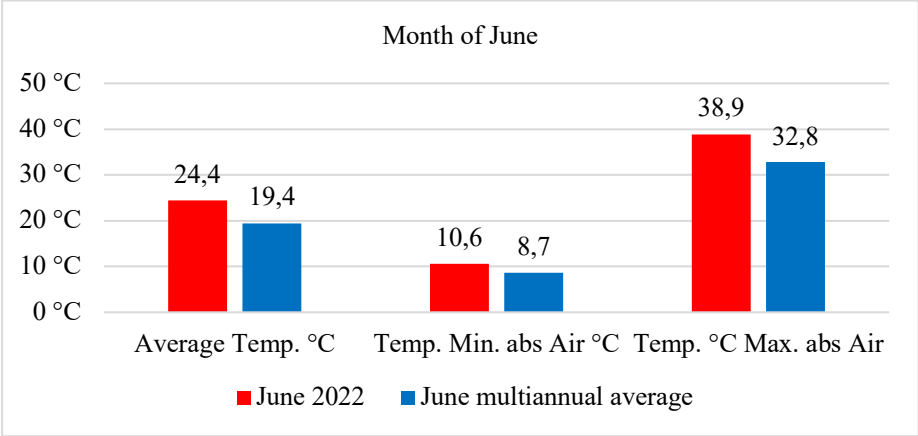

Figure 1. Month of June – Multiannual and 2022 Temperatures

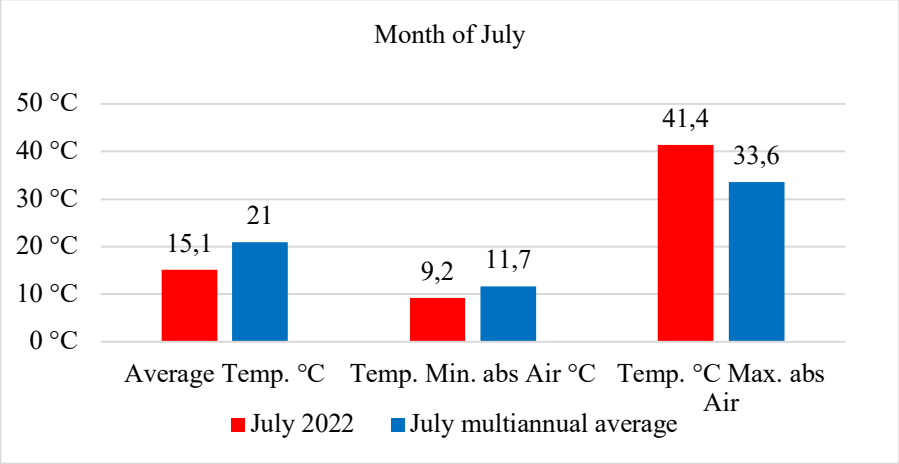

Figure 2. Month of July – Multiannual and 2022 Temperatures

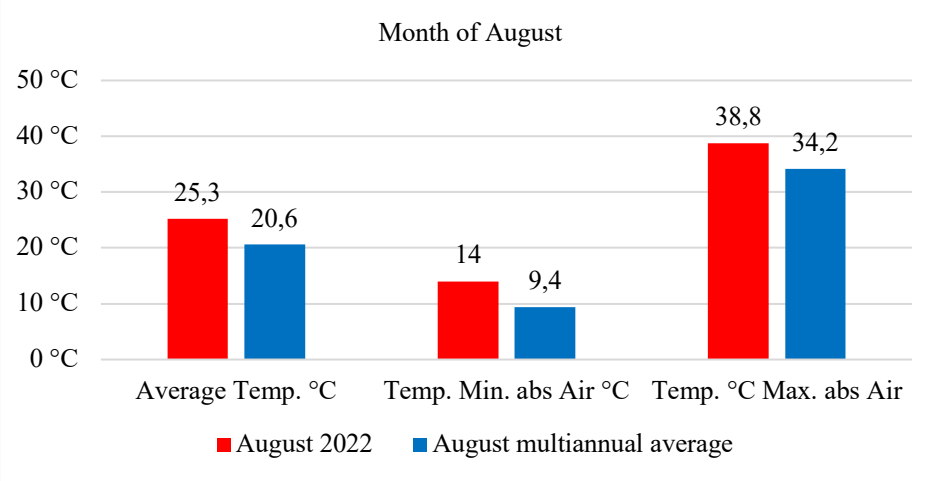

Figure 3. Month of August – Multiannual and 2022 Temperatures

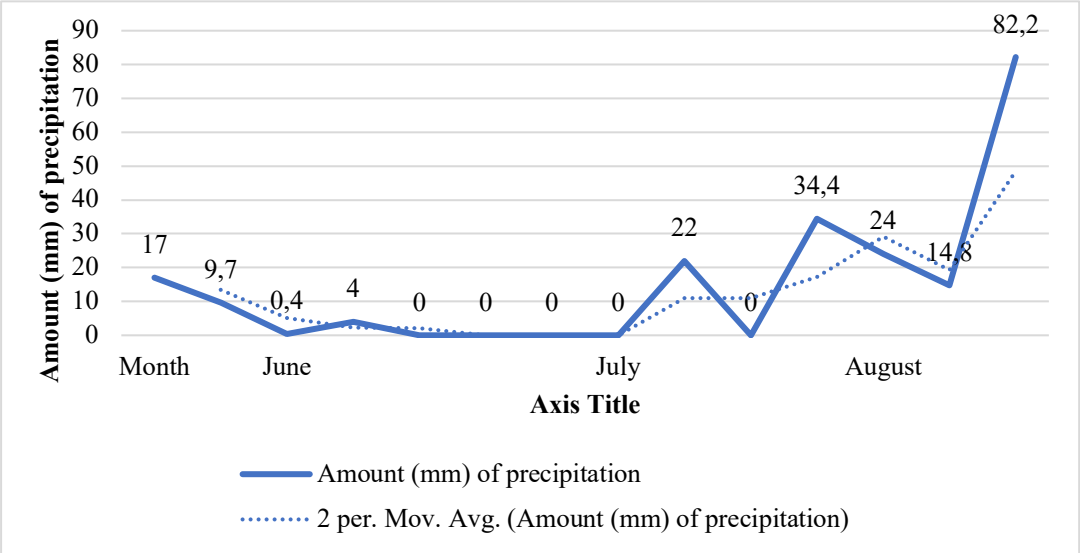

Figure 4. Precipitations from June to August

Figure 4 shows the evolution of precipitation in the months of June - July - August 2022, in the Ghioroc area. At the end of August, the beginning of September, more than 80 mm of precipitation was recorded, compared to the almost totally dry month of July.

Table 3. Structural analysis of grape bunches

Mechanical analysis of grape bunches before harvesting												
		Bunch		Bunches' structure								
Variety	Sample	Bunch weight (g)	Bunch volume (ml)	Berries			Rachis		Berry weight (g)	Pulp weight (g)	Skin weight (g)	Seeds weight (g)
				Weight (g)	No	%	Weight (g)	No				
FR	Whitness	**156**	**140**	**147,8**	**102**	**94,74**	**8,20**	**1**	**1,30**	**1,10**	**0,16**	**0,04**
	Repet. 1	158	145	150,1	131	95,00	7,35	1	1,15	0,82	0,26	0,07
Feteasca regala	Repet. 2	162,2	165	155,2	91	95,68	6,40	1	1,71	1,34	0,29	0,08
26.08.2022	Repet. 3	102	95	97,5	61	95,59	3,50	1	1,60	1,24	0,28	0,08
	Averrage	**140,73**	**135**	**134,27**	**94,3**	**95,42**	**5,75**	**1**	**1,48**	**1,13**	**0,28**	**0,08**
	Repet. 1	272,1	245	254,6	143	93,57	13,00	1	1,78	1,18	0,43	0,17
Feteasca regala	Repet. 2	114,6	100	108,1	51	94,33	6,00	1	2,12	1,57	0,43	0,12
05.09.2022	Repet. 3	143,7	135	135,7	77	94,43	5,50	1	1,76	1,31	0,34	0,12
	Averrage	**176,8**	**160**	**166,13**	**90,3**	**94,11**	**8,17**	**1**	**1,89**	**1,35**	**0,40**	**0,14**
MM	Whitness	**330**	**313**	**315**	**108**	**95,45**	**15,00**	**1**	2,92	2,50	**0,35**	**0,07**
	Repet. 1	143	136	118	94	82,52	25,00	1	1,26	0,96	0,21	0,09
Mustoasa de Maderat	Repet. 2	215	204	201	98	93,49	14,00	1	2,05	1,59	0,38	0,08
26.08.2022	Repet. 3	222	211	210	105	94,59	12,00	1	2,00	1,46	0,45	0,09
	Averrage	**193,3**	**183,7**	**176,3**	**99**	**90,20**	**17,00**	**1**	**1,77**	**1,34**	**0,35**	**0,09**
	Repet. 1	415,1	395	384,6	234	92,65	30,50	1	1,64	1,04	0,43	0,17
Mustoasa de Maderat	Repet. 2	370,7	345	342,5	235	92,39	28,20	1	1,46	0,91	0,43	0,12
05.09.2022	Repet. 3	335	318,25	315,0	227	94,03	20,00	1	1,39	0,92	0,38	0,09
	Averrage	**373,6**	**352,8**	**347,4**	**232**	**93,02**	**26,23**	**1**	**1,50**	**0,96**	**0,41**	**0,13**

Compared to witness/ control – *Feteasca regala* (Constantinescu et all, 1960), the average weight of the grapes improved after the rains at the end of August 2022, from 140.73 g to 176.80 g, which is also easily noticeable in their volume. (Table 3) The weight of the berries also increased, from an average of 134.27 g to 166.13 g. The weight of the cluster (rachis) at the second determination, on September 5, 2022, is within the

standard, 8.17 g, compared to 8.20 g in the Control. The appearance of the grape bunches (elongated, non-winged, with yellow and relatively rare berries), the weight of the pulp and the skins, parameters that have higher values than those of the witness, confirm that the analysis was made on one of the two biotypes of *Feteasca regala*, the other having winged grapes, fuller and with smaller berries.

It is known that in the *Feteasca regala* variety (Constantinescu et all, 1960), the grape bunches do not develop uniformly on the same bush. We can find about 33% grapes in large bunches (over 150g), 40% medium bunches (over 100g) and 27% small bunches, of around 90g, on the same grapevine. Repeat determinations show exactly this uneven distribution, because grape bunches from each size range were analyzed. The *Feteasca regala* variety is relatively resistant to drought, and this aspect is also observed in the analytical values determined especially for pulp weight, which was constantly above the witness even before the rains.

At *Feteasca regala*, the sugar content at the time of structural determinations fluctuated between 195 - 197 g/l, with a total acidity of 4.9 - 6.0 g/l expressed in tartaric acid. The yield at pressing at *Feteasca regala* is between 76.7% by weight (59.7% by volume), with the pomace having about 23.3% of the weight of the grapes.

The *Mustoasa de Maderat* variety is a grapevine variety with poor resistance to drought. In the framework of the structural analysis of grapes, a spectacular improvement of the quantitative parameters is observed after the intake of water from the rains, compared to the suffering determined by the periods of extreme drought. If in the determinations of August 26, 2022, when almost without any exception, all analytical parameters were below the witness, in those from the beginning of September, they even exceed the witness - *Mustoasa de Maderat* (Constantinescu et all, 1959).

The pressing yield at *Mustoasa de Maderat* is between 71.8-72.9% by weight (64.2% by volume), the pomace having about 23.6-28.2% of the weight of the grapes.

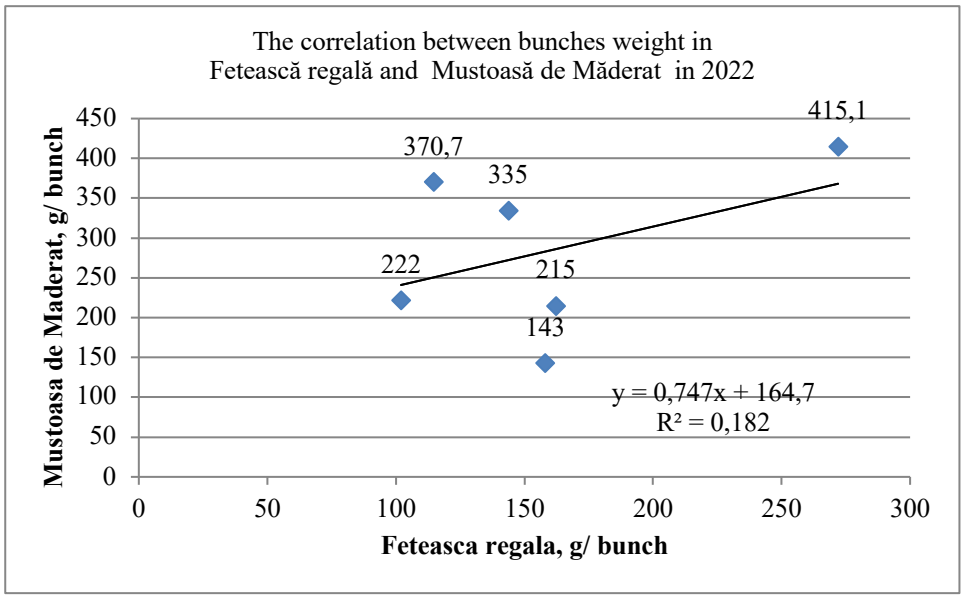

Figure 5. Correlation between the weight of the grapes of *Feteasca regala* and those of *Mustoasa de Maderat*, in the summer of 2022

The *Feteasca regala* variety is considered one of the most productive grape varieties for wine. However, although more resistant to drought than *Mustoasa de Maderat*, in a year with prolonged drought during berry growth and cluster compaction it expresses a more pronounced water stress than it. (Figure 5) *Mustoasa de Maderat* responds more quickly to the water intake during the fallow period, recovering almost instantly the losses suffered during the drought. The leaf with the slightly corrugated limb, the thicker skin of the berries and the abundant fruit wax are protective factors against the negative effects due to drought.

CONCLUSIONS

Under extreme drought conditions, the wine grape production and areas planted with vines will start to decrease annually, the maintenance and management costs of plantations will be higher and higher, and the price per unit of product will have a smaller and smaller marginally profit.

Late-ripening wine grape varieties (*Cabernet Sauvignon*, *Syrah*) will also experience a decrease in quality, due to the dilution of cell juice, augmented by the possible installation of gray rot or the attack of *Drosophylla*

suzukii, on the berries that crack due to turgescence in weight of 5-25%. There is a decrease in the amount and volume of grape seeds for early varieties. The grape berries have remained undersized and lately a process of wilting of the grapes has started and part of the rachis has dehydrated irreversibly. This phenomenon greatly reduced the yield per hectare.

On the scale from 0 to 9, awarded according to the sensitivity to drought, where 0 is extremely resistant and 9 extremely sensitive, the *Feteasca regala* variety would receive a 5, and the *Mustoasa de Maderat* variety a 7.

Comparing the climate parameters of the year 2022 with the multi-year averages, we see a considerable increase in temperatures, both maximum and minimum, which forewarns for the coming years, an increase in the annual average temperature of more than 1.5^{o}C.

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