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THERMAL REGIME DURING COLD ACCLIMATION AND DORMANT SEASON OF GRAPEVINES IN CONTEXT OF CLIMATE CHANGES- HILLS OF CRAIOVA VINEYARD (ROMANIA)

CICHI DANIELA DOLORIS[1], CICHI M.[2], GHEORGHIU N.[1]

[1] University of Craiova. Faculty of Horticulture. Horticulture & Food Science Department

[2] University of Craiova. Faculty of Agronomy

Correspondence author E-mail: daniela.cichi@edu.ucv.ro

mihaicichi@gmail.com

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ABSTRACT

The thermal regime during the autumn-winter seasons plays a decisive role in cold acclimation and survival grapevine in cold climates. This study aims at assessing the time variability of the thermal regime during dormant season, between 1961-2021, in the Hills of Craiova vineyard and its potential implications on the grapevine, especially regarding its acclimation to cold and its vulnerability to frost. The following observations and analytical data were used in order to assess parameters and indicators with negative thermal stress potential: minimum and maximum temperature (daily, monthly averages), absolute maximum and minimum monthly temperatures, the duration of frost (days), the frequency of several low-temperature thresholds and the temperatures preceding frost episodes.

INTRODUCTION

Worldwide, especially in cold climate regions, there are various studies concerning vineyards damaged by winter frosts and cold hardiness of grapevine (Fennell A., 2004; Hubackova M., 1996). With a certain frequency, the damage caused by winter frost to the vine plants can have harmful effects on the viticulture in some wine growing regions of Romania (Bucur G.M. et al., 2020; Cichi D. et al, 2016; Rotaru L. et al., 2010). Considering the climatic changes noticed during the last decades in the world and in the country, beside the phenological, physiological and biochemical perturbations noticed for grapevine during the active vegetation, with direct effects on the quantitative and qualitative level of the wine-growing production, there is the risk of some indirect effects of these perturbations on the cold and frost hardiness of the grapevine (Bucur

G.M. et al., 2016; Kartschall T. et al., 2015; Rotaru L. et al., 2011; Sgubin G.et al., 2018). Moreover, the climatic warming during the autumn-winter season may affect the low temperature needed for the full acclimation to cold and it may affect such the frost hardiness of the grapevine in case of the frosts that may occur subsequently (Ferguson J.C. et al., 2011; Schnabel B.J.et al.,1987).

The Hills of Craiova vineyard includes wine-growing plantations placed on the Getic Plateau. The wine-growing centre of Banu Maracine, situated at 44º19' north latitude and 23º48' east longitude, at about 6 km from Craiova, is the most representative one within the vineyard, as it is especially famous for the DOC wines, which are red and flavoured (Olteanu I.et al., 2002).

This study aims at assessing the time variability of the thermal regime during dormant season, between 1961-2021, in the Hills of Craiova vineyard and its potential implications on the grapevine, especially regarding its acclimation to cold and its vulnerability to frost.

MATERIAL AND METHOD

The following climate indices and analytical data were used in order to assessing parameters and indicators with negative thermal stress potential: means of the daily minimum temperature (TN) and daily maximum (TX), means of the daily mean temperature (TG), absolute minimum temperature (TNn), at monthly, seasonal and annual level. The duration of frost (number of days with TN ≤0°C), the frequency of several low-temperature thresholds and the temperatures preceding frost episodes, were also analyzed.

In order to assess the negative thermal risk during the dormant season, we analyzed the minimum values of daily minimum temperatures (TNn) on different classes of critical temperatures for grapevine, depending on the hardiness potential of the grapevine varieties, respectively: TNn ≤ -15°C…≤-18°C, TNn ≤ -18.1°C... ≤-20°C, TNn ≤ -20.1°C…≤-22°C, TNn ≤ -22.1°C…≤-24°C, TNn ≥ -24.1°C…≤-30°C and we calculated their frequency.

Climate data used in this analysis are for Craiova station for 1962-2020 and were obtained from the National Meteorological Administration and from the following source Klein Tank, A.M.G. and Coauthors (2002, http://www.ecad.eu). The weather Craiova station is located at 44°13` N and 23°52`E, at an elevation of the 192 m.

The features of the data distribution were established by means of coefficients Kurtosis (K) and Skewness (S).

They were calculated the average multiannual values of the average minimum and maximum daily temperatures, the average on 30-years intervals and on 10-years intervals and we noticed certain thermal records at season level and at yearly level.

Equality dispersion testing was performed using F-Test two-sample for variances. The *t-Test: two-sample assuming unequal variances* was used to compare the averages of the analyzed temperatures. For statistical analysis XLSTAT-Pro for Microsoft Excel was used.

RESULTS AND DISCUSSIONS

The cold acclimation and the endo-dormancy as adaptation reactions of the grapevine to low temperatures are essential for its survival and for its cold hardiness. The thermal regime during the autumn-winter seasons plays a decisive role in cold acclimation and survival grapevine in cold climates (Ferguson J.C. et al., 2011).

The distribution tests (Table 1) for multiannual values of mean of daily mean temperature for winter season (TGw) indicate a relatively symmetrical distribution, the Skewness (S) values are quite close to 0 and the Kurtosis (K) values are between -1/2 and +1/2, except for kurtosis between 1991-2020, as it was leptokurtic.

Compared to TGw for the lapse of time 1962-1991, during the last three decades, we noticed an increase of the TGw average (+0.93 °C), while, during the last decade, the increase was +1.40°C (Table 2). The same tendency appears regarding the mean of daily maximum (TXw) and minimum temperature for winter season (TNw), as the differences are significant for $p \leq 0.05$ (table 3 and table 4).

Regarding the autumn thermal regime, during the last 30 years, we noticed an increase compared to the lapse of time 1962-1991 of the monthly average of TG, TX, TN (October and November), but it is not statistically significant. The increase is even more obvious during the last decade, as it is statistically significant for TG October and November (table 1) and TN November (table 3).

January also shows a warming for the last three decades, especially for the last decade, compared to the lapse of time 1962-1991, statistically significant in report to TG, TX and TN for $p \leq 0.05$ (table 2,3 and 4).

During February and March, which are relevant for the eco-dormancy of vine phase, we notice an obvious increase of the thermal regime for the last decades, as the difference is statistically significant ($p \leq 0.05$) only regarding the TX for February, respectively the TX and the TN for March (table 3 and 4).

Table 1

Results of the distribution tests applied on climatic datasets

Climatic Index	Skewness				Kurtosis			
	1962-2020	1962-1991	1991-2020	2011-2020	1962-2020	1962-1991	1991-2020	2011-2020
TGw	0.119	-0.392	0.021	0.359	0.418	-0.491	0.784	0.075
TXw	0.080	-0.305	-0.037	0.988	-0.235	-0.551	-0.367	0.567
TNw	0.077	-0.340	-0.043	-0.813	-0.234	-0.551	-0.366	0.567
TGoct.	0.320	0.815	-0.124	-0.072	-0.064	1.148	-0.322	-1.622
TGnov.	-0.430	-0.429	-0.576	0.006	0.114	0.328	0.387	0.130
TGjan.	-0.237	-0.453	0.421	-1.127	0.731	0.196	0.770	1.288
TGfeb.	-0.318	-0.136	-0.430	-0.843	-0.244	-0.354	-0.131	1.674
TGMar.	0.228	0.204	-0.583	-0.209	0.004	-0.788	0.731	-1.450

The frost period, the moment of frost installation and the frost intensity have decisive roles in the grapevine survival and in its frost hardiness (Ahmedullah M., 1985; Cichi D., 2006).

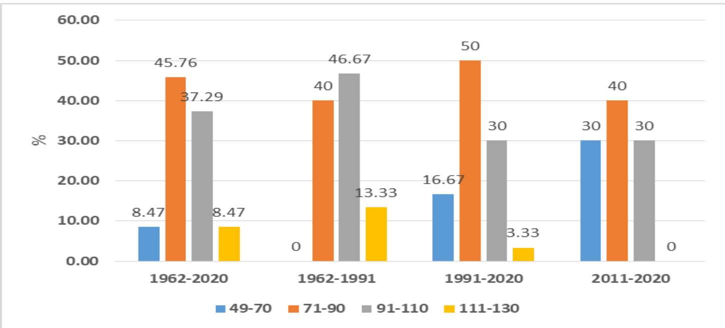

Figure 1. Distribution by frequency classes of Index Frost days (dormant season of vine)

Table 2

Multiannual values of mean of daily mean temperature (°C) during the dormant season of vine, Hills of Craiova vineyard

Climate Index	1962-2020			1962-1991			1991-2020			2011-2020			±	±
	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	$Mean_{1991-2020}$/ $Mean_{1962-1991}$ (°C)	$Mean_{2011-2020}$/ $Mean_{1962-1991}$ (°C)
TGw	3.61	0.93	6.88	3.15	1.02	4.89	4.08	0.93	6.88	4.55	2.82	6.88	+0.93*	+1.40*
TGoct.	11.46	8.15	15.56	11.17	8.15	15.56	11.76	8.56	14.49	12.24	9.67	14.49	-0.29	+1.07*
TGnov.	5.42	-0.37	9.73	5.05	-0.37	8.62	5.78	-0.09	9.73	6.42	2.96	9.73	+0.73	+1.36*
TGjan.	-1.63	-9.06	5.44	-2.27	-9.06	2.76	-0.94	-5.1	5.44	-0.85	-5.1	1.41	+1.33*	+1.42*
TGfeb.	1.29	-5.92	6.68	1.10	-5.79	6.48	1.34	-5.92	6.68	1.61	-5.92	6.57	+0.24	+0.51
TGMar.	6.62	-0.08	14.04	7.00	-0.03	14.04	6.20	-0.08	9.42	6.88	3.75	9.42	-0.80	-0.12

Confidence level for means 95%; TGw- mean of daily mean temperature winter (DJF); *- indicate significance at the $p \leq 0.05$ level

Table 3

Multiannual values of mean of daily maximum temperature during the dormant season of vine, Hills of Craiova vineyard

Climate Index	1962-2020			1962-1991			1991-2020			2011-2020			±	±
	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	$Mean_{1991-2020}$/ $Mean_{1962-1991}$ (°C)	$Mean_{2011-2020}$/ $Mean_{1962-1991}$ (°C)
TXw	8.28	4.46	12.39	7.77	4.83	10.25	8.81	4.46	12.39	9.46	7.84	12.39	+1.04*	+1.70*
TXoct.	17.63	12.89	21.87	17.63	12.89	21.87	17.61	13.44	21.21	18.32	13.95	21.21	+0.02	+0.69
TXnov.	9.74	3.03	15.78	9.53	3.89	15.78	9.92	3.03	14.91	10.44	7.65	14.23	+0.38	+0.90
TX jan.	2.19	-5.69	11.29	1.47	-5.69	8.07	3.00	-1.27	11.29	3.39	-1.02	6.76	+1.53*	+1.92*
TX feb.	5.14	-1.9	13.45	3.96	-0.84	10.21	6.18	-1.9	13.45	6.30	-1.9	11.82	+2.22*	+2.34*
TX Mar.	10.99	3.33	17.51	9.99	3.56	17.51	11.93	3.33	16.61	12.39	3.99	16.61	+1.93*	+2.39*

Confidence level for means 95%; TXw - mean of daily maximum temperature winter (DJF); *- indicate significance at the $p \leq 0.05$ level

Table 4

Multiannual values of mean of daily minimum temperature during the dormant season of vine, Hills of Craiova vineyard

Climate Index	1962-2020			1962-1991			1991-2020			2011-2020			± Mean 1991-2020/ Mean 1962-1991 (°C)	± Mean 2011-2020/ Mean 1962-1991 (°C)
	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.	Mean	Min.	Max.		
TNw	0.06	-2.06	2.69	-0.35	-2.06	1.46	0.47	-1.99	2.69	0.93	-1.47	2.69	+0.82*	+1.28
TNoct.	7.19	4.04	13.49	6.98	4.04	13.49	7.37	4.38	9.53	7.62	5.45	9.44	+0.39	+2.07
TNnov.	2.15	-3.46	7.29	1.69	-3.46	5.42	2.59	-2.73	7.29	3.43	-0.93	7.29	+0.90	+1.74*
TN jan.	-4.68	-11.98	0.99	-5.27	-11.98	-0.65	-4.06	-8.58	0.99	-4.08	-8.58	-1.74	+1.21*	+1.18
TN feb.	-2.75	-9.81	2.98	-3.32	-9.81	1.45	-2.29	-9.68	2.98	-1.69	-9.68	2.98	+1.03	+1.63
TN Mar.	1.26	-4.1	4.81	0.79	-4.1	4.18	1.75	-2.77	4.81	2.47	0.22	4.81	+0.96*	+1.68*

Confidence level for means 95%; TXw - mean of daily minimum temperature winter (DJF); *- indicate significance at the $p \le 0.05$ level

Table 5

Mean value for Index Frost days, Hills of Craiova vineyard

Period	Mean	SD	CV%	Median	Range	Min	Max	Kurtosis	Skewness
1962-2020	89.08	15.95	17.90	89	76	49	125	-0.097	-0.245
1962-1991	94.33	13.04	13.82	93.5	46	71	117	-0.927	-0.136
1991-2020	84.07	16.91	20.11	83.5	76	49	125	0.183	-0.258
2011-2020	79.8	16.72	20.95	81.5	55	49	104	-0.258	-0.333
Period of record -dormant season						2015/ 2016	1995/ 1996		
±% 1991-2020/ 1962-1991	-10.87								

Confidence level for means 95%

The average frost period, expressed by Index frost days dormant season (1962-2020), in the Hills of Craiova vineyard is 89 days, with a maximum registered during the dormant season 1995-1996 (125 days) and a minimum of 49 days (2015-2016).

Compared to the Index frost days dormant season 1962-1991, during the last 30 years (1991-2020), we may notice a decrease of 10.87 % of the average number of days with TN ≤ 0 °C. The shortest average duration of frost is registered in the last decade (Table 5). After the year 1991, we may notice a frequency decrease of the years having a frost duration longer than 110 days (Figure 1).

During dormant season, the critical moment for the grapevine buds starts from the critical temperatures of - 18±3°C in the endo-dormancy and from - 10 ... - 11°C in the eco-dormancy, depending on the variety (Bordelon B.P et al., 1997; Irimia L.M., 2012).

During the last 30 years, we noticed a decrease of 29.62 % of the number of cases with critical temperatures ≤ - 15 ° C for the grapevine (table 6). Considering the Hills of Craiova vineyard, the critical temperatures among -15°C…≤ - 20°C have the highest frequency. Once in about 10 years, the minimum temperatures decrease under - 22°C, causing significant damage both to the buds and to the cane tissues.

Table 6

Relative Frequency (%) of critical thermal classes, Hills of Craiova vineyard

Critical thermal classes TN	1961-1991	1991-2021	1991-2001	2001-2011	2011-2021
-15°C…-18°C	50.02	64.91	75.00	56,52	66,67
-18.1°C... -20°C	23.46	24.56	18.75	34,78	16.67
-20.1°C…-22°C	8.64	7.02	0	8,69	11.11
-22.1°C…-24°C	4.94	3.51	6.25	0	5.55
-24.1°C…-26°C	2.47	0	0	0	0
-26.1°C…-30°C	2.47	0	0	0	0
No.cases/period	81	57	16	23	18
Record no.casses/ dormant season	19/1962-1963		5/1997-1998	6/2004-2005 and 2005-2006	8/2011-2012

The highest number of cases with TN ≤ - 15 ° C in Hills of Craiova vineyard was registered during dormant season 1962-1963 and, in the last decade, during dormant season 2011-2012 (table 6).

Table 7

Critical temperature during eco-dormancy of vine, Hills of Craiova vineyard

Period	February	March
1961-1991	-15.7/20Feb.1967 -15.4/9Feb. 1976 -17.6/9Feb. 1976 -17.0/10Feb. 1976 -16.6/Feb. 1976 -17/2 Feb. 1991 -14/ Feb. 1991	-15.7/1 Mar.1986 -19.4/5 Mar.1987 -16.4/6 Mar.1987 -15.2/7 Mar.1987
1991-2001	-16.5/1 and 3 Feb.1996 -17.5/ 2 Feb. 1996	-
2001-2011	-14.4/14 Feb.2004	-12.7/2 Mar.2005
2011-2021	-15.4/8Feb. 2012 -22.6/9Feb. 2012 -17.1/10Feb. 2012 -15.2/11Feb. 2012	-14.4/ 1 Mar.2018

Within the climate warming tendency in midwinter, it is obvious the risk of occurrence of some critical temperatures ≤ - 15°C during the eco-dormancy (February, March), especially in the last two decades (table 7). There is such a risk once every 1-2 years out of 10, as the absolute minimum temperature may even reach -22.6 °C (February, 2012).

Oşlobeanu M. et al., (1980) specify that the grape buds surprised in October-November by the low temperatures (-10...-12°C) are 90-100% damaged. Considering our observations, this risk is very low in the Hills of Craiova vineyard (5 years out of 60), as the record was registered in 1993 with 4 cases of TN ≤ - 10.5°C and -16.2°C / 19 November 1993.

CONCLUSIONS

Compared to the years between 1962-1991, during the last three decades, we 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 frosts that may occur subsequently.

In Hills of Craiova, in the last three decades, we notice a decrease of 29.62% of the number of cases with critical temperatures ≤ - 15 °C. However, the risk of negative critical temperatures among -18 °C... -22 ° C stays high (2-3 years out of 10). In these conditions, we recommend to choose very carefully the range of varieties (depending on the frost tolerance threshold), to protect the vines in young vineyards (the first two years since planting), to provide a technical and phytosanitary management able to provide good maturation for the shoots.

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