EVOLUTION OF GRAPES' TITRATABLE ACIDITY AND SUGAR CONTENT IN RELATION TO CANOPY MICROCLIMATE IN THE COTNARI WINE GROWING REGION CONDITIONS

EVOLUŢIA ACIDITĂŢII TOTALE ŞI A CONŢINUTULUI DE ZAHARURI AL STRUGURILOR PE PARCURSUL MATURĂRII ÎN RELAŢIE CU MICROCLIMATUL TUFEI ÎN CONDIŢIILE PODGORIEI COTNARI

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Abstract: *High temperatures and high values of solar radiation during grape ripening lead to excessive sugar accumulations and low titratable acidity, with negative consequences on the sensory profile of the grapes and wines. The control of these unfavourable developments for the chemical composition of the grapes becomes a base condition for obtaining quality wines in the context of climate change. The research was carried out in 2020, on Tămâioasă românească wine grape variety in the Cotnari wine growing region, during the grape ripening season. The study revealed: positive correlations between the helio-thermal factors and grapes sugar content; negative correlations between the same climatic factors and grapes titratable acidity; and the influence of some cultural practices on grapes chemical composition. The grapes on the west side of the row have accumulated less sugars during ripening: 137.64 g / L on the west side and 145.72 g / L on the east side; grapes acidity on the west side was also more pronounced, with 13.61 g / L tartaric acid compared to 12.69 g / L tartaric acid on the east side. The 6% bentonite film treatment reduced the impact of temperatures and solar radiation on titratable acidity of the grapes, maintaining it by 0.83 g / L tartaric acid higher than the control.*

Key words: climate change, grape ripening, Tămâioasă românească, total acidity, sugars**.**

Rezumat. *Temperaturile ridicate şi valorile mari ale radiaţiei solare din timpul maturării strugurilor duc la acumulări excesive de zaharuri şi deficit de aciditate, cu efecte negative asupra echilibrului organoleptic al strugurilor şi vinurilor. Controlul acestor evoluţii nefavorabile pentru compoziţia chimică a strugurilor devine o condiţie de bază pentru obţinerea vinurilor de calitate în contextual schimbării climatice. Cercetarea a fost efectuată în anul 2020, asupra soiului Tămâioasă românească, în condiţiile podgoriei Cotnari, în perioada maturării strugurilor. Rezultatele relevă corelaţiile pozitive dintre*

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factorii helio-termici şi conţinutul de zaharuri, corelaţiile negative dintre aceeaşi factori şi aciditatea totală a mustului, precum şi influenţa unor intervenţii tehnologice asupra parametrilor de compoziţie ai strugurilor. Strugurii de pe partea umbrită a rândului au acumulat mai puţine zaharuri pe parcursul maturării, în medie137,64 g/L pe partea vestică şi 145,72 g/L pe partea estică; aciditatea totală a mustului a fost de 13,61 g/L ac. tartric pe partea vestică şi 12,69 g/L ac. tartric pe partea estică. Tratamentul cu film de bentonită 6% a redus impactul temperaturii şi radiaţiei solare asupra acidităţii titrabile a strugurilor, menţinând un nivel mai ridicat cu 0,83 g/L ac. tartric comparativ cu martorul.

Cuvinte cheie: schimbări climatice, maturarea strugurilor, Tămâioasă românească, aciditate totală, zaharuri.

INTRODUCTION

Researches carried out in recent decades has shown that climatic factors determine the specifics of vineyards, behaviour of vines, the chemical composition of grapes (Santos *et al*., 2011; Bock *et al*., 2013) and quality of wine (Jones *et al*., 2005a; Orduna, 2010). For this reason, climate change will be a major challenge for viticulture, which winegrowers must find solutions to. In order to maintain the quality and typicity of grapes and wines, one of the effective adaptation measures could be to improve the microclimate of the vine canopy.

Studies on the influence of climate change on viticulture are based on an assessment of their impact on local wine growing regions (Duchene and Schneider, 2005; Ruml *et al*., 2012; Koufas *et al*., 2014; Bock *et al*., 2011; Tomasi *et al.*, 2011; Irimia *et al*., 2017, 2018), and at global level (Hannah *et al*., 2013; Moriondo *et al.,* 2013; Toth and Vegvari, 2016). Several studies, mainly based on statistics, have addressed the impact of climate change on vine production and phenology (Webb *et al.,* 2007, 2011; Malheiro *et al.,* 2013; Santos *et al.,* 2011; Moriondo *et al.,* 2015).

According to the characteristics of the current climate, some areas are not suitable for viticulture, but with expected climate change, they could, in the future, play an important role in viticultural landscape (Fraga, 2016).

Cotnari wine growing region is located in the continental temperate climate Dfa and Dfb (Koppen-Geiger climate classification). Research to date indicates that the Cotnari climate has changed over the past 30 years as a consequence of climate change, becoming more suitable to the production of quality white wines, richer in heliothermic resources and suitable even for the production of red wines (Irimia *et al.,* 2018). In 2050-2070, it is expected that temperatures will exceed those suitable for the production of quality wines in this wine growing region (Irimia *et al.,* 2019), thus finding early solutions to allow the preservation of the local wine grape variety and the specific of the grapevine cultivation is necessary.

Globally, various cultural practices have been experimented to balance the composition of grapes, such as the use of a bentonite film, partial removal of leaves, leaf removal of the upper third of the shoots, shading of the vine canopy and others. They have provided results depending on the local climate and the specifics of the wine growing region. Since most practices require manual labour and high costs, one of the alternatives could be treatment of the vine leaves with reflective inert particles.

Taking into account the need for adaptation measures and given that several studies have reported and projected the increase in incident solar radiation and temperature for most of the world's wine regions (Jones *et al*., 2005; Moriondo *et al.,* 2013), this study aimed to evaluate and compare the effects of bentonite film treatment of the vine's canopy, with those of different methods of leaf removal, on the quality of Tămâioasă românească (the evolution of sugars and acidity during maturation was registered in order to observe the effects of bentonite film and the two types of leaf removal) grape variety of *Vitis vinifera* cultivar.

MATERIAL AND METHOD

The studied area has about 1600 ha and is located in the Cotnari wine growing region. The experimental field is organized in the Tămâioasă românească plantation at 199 m asl (height above sea level) elevation and has a south-eastern exposition. The vine is planted at a distance of 1 meter between plants per row, 3 meters between rows and is pruned on an 80 centimeters trunck with bilateral cordon. It was pruned into spurs and canes with a load of 30 eyes on the vine.

Tămâioasă românească is a white wine grape variety well adapted to the pedoclimatic conditions of the Cotnari wine growing region, due to the long and sunny autumns that characterize the region. Under the Cotnari wine growing region conditions, this variety reaches high sugars accumulations at full ripening (200-210 g/L) and varietal-specific aromas. From the point of view of biological resistances, the Tămâioasă românească variety is sensitive to low winter temperatures around -18 to -20 ^{o}C, to drought and excess moisture, is strongly attacked by diseases, grape moths and wasps (Dobrei *et al.,* 2008). The cultivation of the variety requires well-defined areas, because of its low ecological plasticity (Tamâioasa românească grape variety needs a location protected from low temperatures. It should have a favourable exposure to reach its full potential).

The experimental field is represented by a 5 year old Tămâioasă românească plantation and comprises 5 experimental variants and a control variant. Each experimental treatment is represented by 30 vines

The experimental treatments are:

V0 – control, without leaf removal and bentonite treatment;
V1 – leaf removal in the cluster zone at verasion;
V2 – leaf removal above the cluster zone at verasion;
V3 – treatment with 1% bentonite solution at verasion;
V4 – treatment with 3% bentonite solution at verasion;
V5 – treatment with 6% bentonite solution at verasion.

Between August 3rd and September 9th 2020, nine grape samples were analysed (tab. 1 and tab. 2). In each experimental variant, two samples of grapes were collected, one from the east side and one from the west side of the row, each represented by 400 berries (approximately 500 g). From each sample, must was extracted and the following analyses were performed: sugar content (g/L); titratable acidity (g/L tartaric acid); pH; density. The evolution of the chemical composition of grapes in each variant was monitored and the results were compared with those of the control variant. The link between the composition of the grapes and the heliothermic values was highlighted.

Temperatures at the vineyard level were monitored by using Tinytag Talk 2 TK 4014 data loggers, placed on the vine row, at the canopy level (about 1.5 m high). At the same time with grape sampling, the following climate parameters were determined by using the 4332 Enviro-Meter™: grape temperature; solar radiation at berry level; air movement at vine row level; air moisture at grape level. The aim is to find the experimental variant that provides a balanced gluco-acidimetric index and a low pH of the grapes must (Irimia, 2012).

RESULTS AND DISCUSSIONS

1. Evolution of air temperatures during maturation

Figure 1 highlights the evolution of temperatures (Min – Max) during maturation (August 1st to September 30th 2020), recorded by using the Tinytag Talk 2 TK 4014 data loggers, placed at canopy level (1.5 m high), temperature recorded at every one hour.

During ripening, the sugar content increases and the acidity decreases until full maturity is reached. The rhythm of sugar accumulation and titratable acidity diminishing is directly influenced by temperatures.

Titratable acidity decreasing is influenced by temperature, especially by the type of organic acid used as a respiratory substrate: at daily temperatures between 30-37 ºC the vine uses malic acid as a respiratory substrate, allowing the production of more velvety wines.

According to the data shown in figure 1, the temperatures recorded during grapes maturation show two highlights in the periods August 6th - 8th and August 29th – September 1st, when temperatures above 32 ºC were revealed. Photosynthesis in the case of temperatures above 32 ºC is slowed and at more than 35 ºC is blocked.

The highest temperature (35.5 ºC) of the ripening period is recorded on the last day of August (fig. 1).

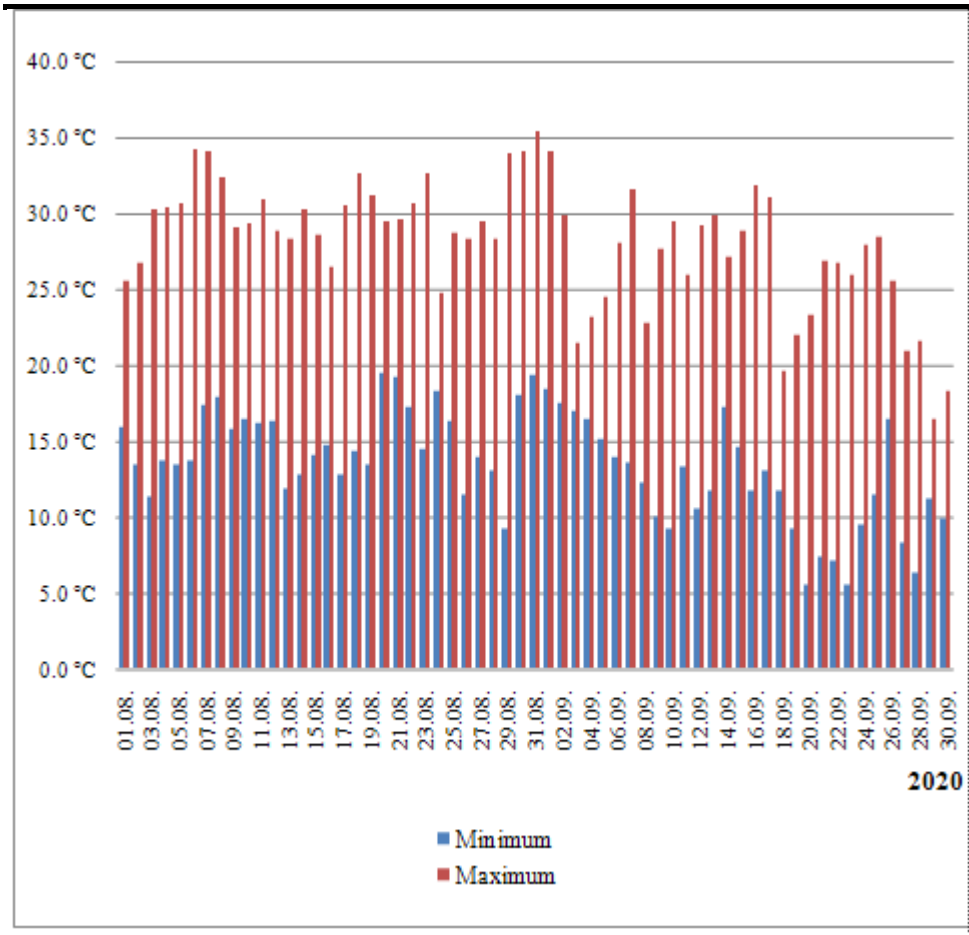

Fig. 1 Evolution of air temperature at plot level during grape ripening between August and September 2020

2. Evolution of grapes sugars content during ripening, in relation to the temperature level

The impact of temperature on sugar accumulation is best observed in figure 2, where the leafy variant next to grapes V1 (137.36 g/L), on the east side accumulated significantly higher quantities than the control variant, on the same side (151.04 g/L) (tab. 1). The direct exposure to solar radiation increased the temperature of the grapes, which intensified the process of sugar accumulation. The protected variant with 6 % bentonite film (V5) is more balanced, with close values between the east side (207.9 g/L) and the west side (205.7 g/L) on the last day. This is due to the bentonite film that protects the leaves from high temperatures.

At full maturation there were significant differences in the amount of sugars accumulated on the east side, compared to the west one. The east side recorded higher values for each variant, indicating a clear influence of the temperature difference. In general, grapes on the colder side recorded lower sugar levels. However, the greatest amount of sugars was recorded in the case of the leafy variant next to the grapes on the east side (V1 E = 221.7 g/L), which benefited from higher temperatures at the level of the grapes. The increase in the amount and concentration of sugars and the decrease in titratable acidity is closely related to recorded temperatures.

Table 1

Evolution of grapes sugar content (g/L) during ripening at the *Tămâioasă românească* variety in different experimental situations

Variant*	03.08.2020	07.08.2020	11.08.2020	15.08.2020	19.08.2020	26.08.2020	01.09.2020	06.09.2020	12.09.2020	**Average during maturation**
V_0 E	68.88	103.6	107.9	122.9	149.2	155.9	173.6	171.5	182.8	**137.36**
V_0 W	68.88	90.8	105.7	120.8	131.6	138.2	167	169.3	164.8	**128.56**
V_1 E	80.36	84.5	122.9	144.8	155.9	144.8	191.9	212.5	221.7	**151.04**
V_1 W	80.36	84.5	122.9	125.1	149.2	147	185.1	182.8	210.3	**143.03**
V_2 E	77.08	88.6	107.9	129.5	155.9	162.6	194.2	201.1	212.5	**147.71**
V_2 W	77.08	88.6	107.9	129.5	155.9	151.5	158.1	194.2	207.9	**141.19**
V_3 E	59.04	99.3	110	131.6	160.4	164.8	194.2	191.1	210.3	**146.75**
V_3 W	59.04	99.3	110	125.1	158.1	142.6	164.8	182.8	207.9	**138.85**
V_4 E	75.44	95	114.3	125.1	162.6	164.8	191.9	180.5	205.7	**146.15**
V_4 W	75.44	95	114.3	122.9	151.5	153.7	167	173.6	196.5	**138.88**
V_5 E	68.88	88.6	114.3	125.1	151.5	158.1	187.4	205.7	207.9	**145.28**
V_5 W	68.88	88.6	114.3	116.5	138.2	149.2	158.1	178.3	205.7	**135.31**

* V0 E = control, east side; V0 W = control, west side; V1 E = leaf removal in the cluster zone, the east side; V1 W = leaf removal in the cluster zone, the west side; V2 E = leaf removal above the cluster zone, the east side; V2 W leaf removal above the cluster zone, the west side; V3 E = treatment with bentonite film (1%), east side; V3 W = treatment with bentonite film (1%), west side; V4 E = treatment with bentonite film (3%), east side; V4 W = treatment with bentonite film (3%), west side; V5 E = treatment with bentonite film (6%), east side; V5 W = treatment with bentonite film (6%), west side.

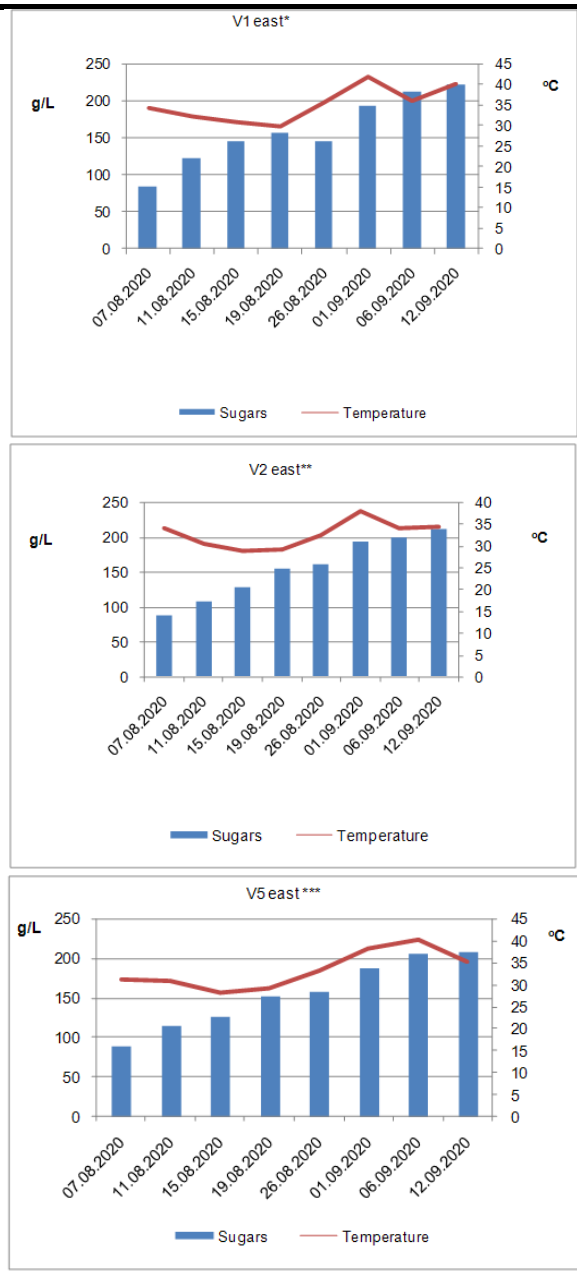

Fig. 2 Evolution of sugars accumulation in relation with grapes temperature
*V_1 E= leaf removal in the cluster zone (east side)
**V_2 E= leaf removal above the cluster zone (east side)
***V_5 E = treatment with 6 % concentration bentonite solution (east side)
[1]east average

3. Evolution of titratable acidity during grape ripening, in correlation with solar radiation and temperature

Table 2

Evolution of grapes titratable acidity (g/L tartaric acid) during ripening at the Tămâioasă românească variety in different experimental situations

Variant*	03.08.2020	07.08.2020	11.08.2020	15.08.2020	19.08.2020	26.08.2020	01.09.2020	06.09.2020	12.09.2020	**Average during ripening**
V_0 E	33.66	19.9	16.8	12.2	9.2	6.9	5.4	3.1	5.4	12.51
V_0 W	33.66	23	18.4	13.8	10.7	9.2	6.1	5.4	6.1	14.04
V_1 E	28.30	27.54	13.8	10.7	8.7	8.4	4.6	3.1	3.8	12.10
V_1 W	28.30	27.54	13.8	13.8	9.2	8.4	5.4	5.4	5.4	13.03
V_2 E	27.54	26.01	18.4	12.2	9.9	7.7	5.4	3.1	3.8	12.67
V_2 W	27.54	26.01	18.4	13.8	9.9	8.4	8.4	4.6	3.1	13.35
V_3 E	32.13	24.48	16.8	13.8	9.2	8.4	5.4	3.8	2.3	12.92
V_3 W	32.13	24.48	16.8	15.3	9.9	9.2	7.7	6.1	3.8	13.93
V_4 E	29.07	23.71	16.1	15.3	8.4	7.7	5.4	3.8	3.8	12.59
V_4 W	29.07	23.71	16.1	16.1	9.2	8.4	6.1	5.4	4.6	13.19
V_5 E	29.83	26.01	16.83	12.2	12.2	7.7	6.1	4.6	4.6	13.34
V_5 W	29.83	26.01	16.83	13.8	13.8	9.2	6.1	6.1	5.4	14.12

* V0 E = control, east side; V0 W = control, west side; V1 E = leaf removal in the cluster zone, the east side; V1 W = leaf removal in the cluster zone, the west side; V2 E = leaf removal above the cluster zone, the east side; V2 W leaf removal above the cluster zone, the west side; V3 E = treatment with bentonite film (1%), east side; V3 W = treatment with bentonite film (1%), west side; V4 E = treatment with bentonite film (3%), east side; V4 W = treatment with bentonite film (3%), west side; V5 E = treatment with bentonite film (6%), east side; V5 W = treatment with bentonite film (6%), west side.

As noted in table 2, the average acidity during maturation retains higher values in the case of the treatment with 6 % bentonite film on the west side (14.12 g/L tartaric acid). This treatment has a higher average than in the case of the control variant, on the same side (14.04 g/L tartaric acid). In common maturity, there were significant differences between the amount of acids accumulated on the east and the west side. The west side recorded higher values for each treatment, indicating a clear effect of the difference in temperature and heatstroke. In general, grapes on the west side recorded higher levels of titratable acidity.

Treatment with bentonite film 6% reduced the impact of temperature and solar radiation on the titratable acidity of grapes, maintaining a higher level by 0.83 g/L tartaric compared to the control variant.

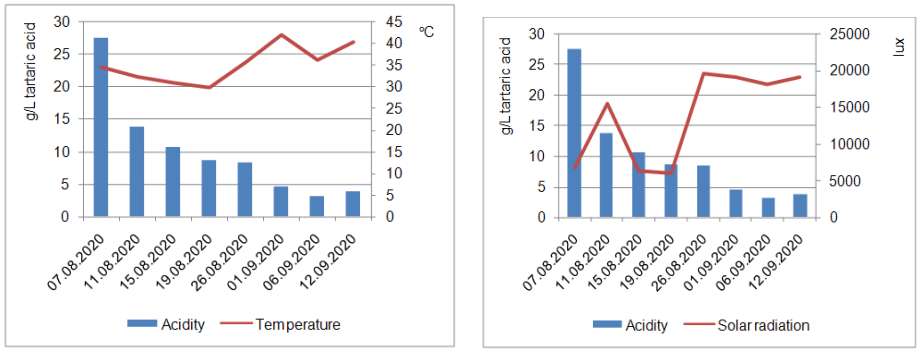

Fig. 3 The evolution of acidity depending on solar radiation and temperature, at the leaf removal treatment (V1 east side)

Solar radiation and temperature are closely related to the evolution of titratable acidity, as seen in the case of the variant with leaf removal next to grapes (fig. 3), which decrease slower as the radiation and temperature values rise. The leaf removal next to the grapes, on the east side, has the lowest acidity value (3.8 g/L tartaric acid), which demonstrates that solar resources are closely related to the decrease in acidity.

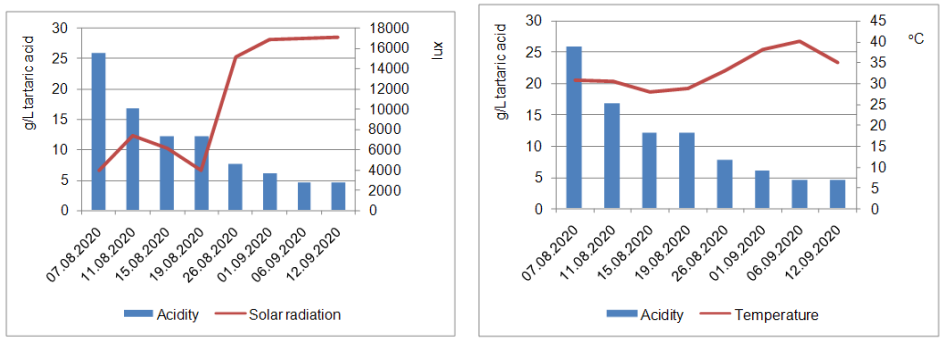

Fig. 4. Evolution of grapes total acidity in relation to solar radiation and temperature, at treatment with bentonite film (V5 east part)

As shown in figure 4, between climatic factors and total acidity is a negative correlation. Acidity in the case of the treatment with 6 % concentration bentonite film is better preserved and of all experimental variants (west part = 5.4 g/L tartaric acid; east side = 4.6 g/L tartaric acid).

The variants where leaves were removed, due to the direct exposure of the grapes to the solar radiation and high temperatures, have accumulated large amounts of sugars, but show acidity deficiency and the resulting wines would lack freshness. In the case of treatment with bentonite film, the most balanced and suitable composition is the 6 % bentonite film (west side: sugars = 205.7 g/L; acidity = 5.4 g/L tartaric acid; east side: sugars = 207.9 g/L; acidity = 4.6 g/L

tartaric acid). This treatment can be considered for the purpose of obtaining a quality wine due to the balance between acidity and sugars (tab. 1 and tab. 2). Thanks to bentonite film protection against climatic factors, a satisfactory balance between sugars and acidity was achieved.

CONCLUSIONS

High temperatures and high values of solar radiation during grape ripening lead to excessive sugar accumulation and titratable acidity deficiency, with a negative effect on the sensory balance of grapes and wines.

Control of these unfavourable developments for the chemical composition of grapes becomes a basic condition for the production of quality wines in the context of climate change.

Research carried out on the Tămâioasă românească variety under the conditions of the Cotnari wine growing region, during the ripening period of the grapes indicate the positive correlations between temperature – solar radiation and sugar accumulations, the negative correlations between the same climatic factors and total acidity, as well as the influence of technological interventions on the parameters of grapes chemical composition.

Grapes on the west side of the row accumulated fewer sugars during maturation (137.63 g/L in shaded – 145.71 g/L in east, the averages of the sugar content evolution between August 3rd – September 12th 2020) and have an higher level of titratable acidity (13.61 g/l tartaric ac. for the west side – 12.68 g/l tartaric acid for the east side, as averages of the evolution of acidity between August 3rd – September 12th 2020).

Treatment with bentonite film 6% reduced the impact of temperature and solar radiation on grapes titratable acidity, maintaining a higher level by 0.83 g/l tartaric compared to the control variant.

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