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RESEARCH ON INCREASING THE ADAPTATION CAPACITY OF GRAPEVINE TO CLIMATE CHANGE - TREATMENTS WITH KAOLIN AND ZEOLITES

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Abstract

Climate change, global warming with the increase of thermohydric stress during the ripening of the berries, the greater frequency of extreme climatic phenomena, etc., produce physiological and biochemical changes in the growth and fruiting of the vine, influencing the production of grapes and especially its quality. The experience carried out in 2022 and 2023 on the 'Fetească regală', under the conditions of the experimental plantation of the UASVM Bucharest Romania, aimed at mitigating the effects of summer thermohydric stress, by applying treatments with kaolin and zeolite in concentrations of 3 and 5 %. After applying the treatment, the intensity of photosynthesis and transpiration was determined, the quantity and quality of the harvest. The variant zeolite 5% stood out, where intensity of photosynthesis increased by 7.6 µmol CO_2 m^{-2} s^{-1} in 2022 and 4.45 µmol CO_2 m^{-2} s^{-1} in 2023, compared to the control; and the transpiration rate decreased by 2.24 mmol H_2O m^{-2} s^{-1} compared to the control, in 2022, for the zeolite 3% variant. Also, the concentration of sugars decreased by 3.67ºBrix in 2022 and 1.66 in 2023, for the zeolite 3 and 5% variants.

Key words: *climate change, foliar application, heat waves, kaolin, zeolites*

INTRODUCTION

According to projections by the Inter-governmental Panel on Climate Change (IPCC, 2014), the global average surface temperature of the Earth is likely to increase this century by between 1.8 and 4.0°C. In this context, it is important to implement innovative measures to mitigate and combat the negative effects of climate change.

Grapevines are one of the plants most affected by these changes, being increasingly subject to radiation, heat and water stress, with negative effects on production and especially its quality.

Numerous studies over the years have established the optimal temperature values for photosynthesis and sugar accumulation in berries (25-30°C) and for anthocyanin accumulation (17-26°C). Lower values are also favourable for the accumulation of aromatic compounds (Mori et al., 2007; Tarara et al., 2008). Research carried out in Australia by Coombe (1987) established that temperatures between 25 and 28°C provide an optimum ratio of sugars to anthocyanins.

Exceeding these intervals, due to global warming, especially during the grape ripening period, and heat waves have led to a series of negative reactions: very high accumulation of sugars in the berries, with marked degradation of acidity, increased pH values, development of atypical aromatic compounds, the phenolic maturity being also affected. Thus, the resulting wines are less suitable for maturation, have a modified aromatic profile and a weaker colour (Palliotti et al., 2015; Martinez de Toda & Balda, 2015; van Leeuwen et al., 2019; Reynold, 2021).

At all meteorological stations in Romania was found an increase in the average annual temperature and a shortening of the transitional seasons (spring and autumn), which indicates a tendency for temperate zones to move closer to subtropical climate conditions.

In most of the country's vineyards, studies have shown significant warming with an influence on the development of the phenological stages of grapevine, the main physiological processes, vegetative growth, grape production and quality (Enache & Donici, 2014; Irimia et al., 2015; Dobrei et al., 2017; Bucur et al., 2019; Cichi et al., 2019; Stroe & Cojanu, 2019).

Șerdinescu et al. (2014), found an increase in mean air temperature between 2000 and 2010 in the main vineyards of the country, with values ranging from 0.7 to 2.1ºC. The largest differences were recorded in Dealu Mare, Târgu Bujor and Murfatlar vineyards highlighting their aridization trend.

Research carried out in 7 centres located in different regions of the country, over a period of 40 years (1977-2016), (Bucur & Dejeu, 2016) found significant increases in mean annual temperatures between from 1.2ºC (Bucharest) to 2.5ºC (Cluj Napoca). Similar increases (1.2-2.3ºC) were recorded during the growing season of grapevines (April-October), while in the hottest month of the year (July), the maximum temperature increases were much higher (3.2-5.5ºC).

Heat waves, assessed on the basis of the number of days with maximum temperatures above 30ºC and 35ºC (the heat wave threshold), showed a distinct statistically significant upward trend in all 7 centres studied in the country (Bucur & Babeș, 2016). Increasing the number of days with Tmax > 35ºC determined a reduction in grape production, average berry mass, a decrease in acidity and an increase in the concentration of sugars in the berry. Due to the intense solar radiation and extreme temperature values during the ripening period of the grapes (4 consecutive days with Tmax > 40ºC), sunburn was recorded on the grapes on the western side of the rows oriented in the N-S direction. Under these conditions, the application of shoot topping and the defoliation with the removal of part of the most photosynthetically active leaves, to the 'Fetească regală' in 2017-2019, led to statistically significant results, reducing these shortcomings, through lower sugar accumulation (by 1.3ºBrix), maintaining acidity in normal parameters (Bucur, 2021).

To mitigate the negative effects, viticulture has a series of **innovative measures** to delay the ripening of grapes and obtain balanced wines with an average alcohol content, namely: *short-term measures* - soil maintenance (Dhanush & Patil, 2020; Buesa et al., 2021), plant management (Palliotti et al., 2014; Silvestroni, et al., 2019), choice of harvest time, winemaking techniques; *in the medium term* - the orientation of the rows, the choice of land for planting, the use of suitable rootstocks (Carvalho et al., 2020) and *in the long term* - the use of irrigation, even late, obtaining new varieties more adapted to these conditions (Caccavello et al., 2019; Miras-Avalos & Araujo, 2021).

Short-term strategies are of particular importance, especially interventions on the foliar apparatus (severe shoot topping, defoliation of the stumps with the removal of part of the most photosynthetically active leaves, applied to the grape veraison and treatments with natural products that protect plants from the effects of radiation and thermohydric stress - kaolin and zeolite).

The use of substances with antiperspirant action causes a partial closing of the stomata, a reduction of photosynthesis and water loss through transpiration.

Spraying plants with kaolin, a natural clay product, has been shown to be effective by forming a film on the surface of the leaves to reflect light and protect against heat stress and water deficit.

By foliar application of a repeated **kaolin** treatment (5%), immediately after the grapes veraison, an increase of 40% in total phenolics, 24% in flavonoids and 32% in anthocyanins was obtained in Touriga National cultivated in the Douro region (Portugal) under conditions of heat and water stress (Dinis et al., 2016; Valentini et al., 2021). Applying a treatment to the Pinot noir variety with kaolin (3%), on the western side of the row, at the beginning of August caused a reduction in leaf temperature by 4-6ºC compared to the control, ultimately leading to a 27% increase in production, a anthocyanin content by 35% and acidity by 11%. The observations were made during the 2017 heat wave in the Umbria region of Italy (Frioni et al., 2019; Singh et al., 2020). Together with kaolin, the use of **zeolite** is a viable and innovative alternative in the sustainable approach to mitigating the effects of global warming and heat waves during the grape ripening period, as well as in the field of disease and pest control allowed in organic farming. Natural zeolite is a sedimentary rock of volcanic origin, composed of hydrated aluminosilicates of calcium, sodium, potassium, magnesium, manganese etc. They used zeolites to control gray rot (*Botrytis cinerea*) and grape moth (*Lobesia botrana*) compared to the application of synthetic fungicides and insecticides in the Abruzzo region of Italy (Calzarano et al., 2019).

The results were comparable to those obtained in the case of the use of synthetic pesticides, without affecting the production and quality of the grapes (accumulation of sugars, titratable acidity and pH). In addition, the application of zeolites led to an increase in the concentration of anthocyanins and an improvement in the color of the wines. This result is similar to that of foliar application of kaolin, which is an inert, radiation-reflecting mineral capable of reducing leaf temperature and influencing major secondary metabolic pathways leading to the biosynthesis of anthocyanins, phenolic and flavor compounds.

This study proposed to analyse the effect of the application of two natural antitranspirant substances (kaolin and zeolite, in different concentrations), on certain physiological parameters and the composition of grapes in the 'Fetească regală'.

MATERIALS AND METHODS

Experimental conditions and the biological material

The research was carried out during the vegetation period related to the years 2022 and 2023, two dry years in which numerous heat waves were recorded, in the experimental plantation within the UASMV Bucharest (N Lat.: 44° 47' 07"; E Long .: 26° 07' 28"; alt. 87 m), on the variety to 'Fetească regală' clone 21 Bl, grafted on Kober 5 BB rootstock. The vine planting distance is 2.2 m x 1.2 m, resulting in a density of 3788 plant ha-1, and the pruning type is bilateral cordon with spur pruning system and loading of 12 buds/m^2.

The vines is grown in a conventional system, without irrigation aid and phytosanitary treatments against to control diseases and pests have been applied in accordance with local standard practice. Soil management provides for natural ground cover and on the row of vines by herbicide.

The experimental variants

The experimental design included 100 vines distributed in five randomized blocks in three different rows. Each block consisted of 20 vines, on which foliar treatments with kaolin and zeolite were applied in different concentrations:

→ Control - untreated control vines;

→ KAO - spray treatment with kaolin, in 3% and 5% concentration;

→ ZEO - foliar treatment with Romanian natural zeolite, in 3% and 5% concentration.

The suspensions were carefully sprayed on both sides of the canopy using a backpack sprayer (Figure 1), once, shortly after entering the veraison phase (August 05 - DOY 217, în anul 2022 si pe August 03 - DOY 215, în 2023). A guard row was left between the experimental variants.

Parameters determined

▪ *Leaf gas exchange measurements*

Photosynthesis intensity (A) (μmols CO_2 $m^{-2}s^{-1}$) and transpiration intensity (E) (mmol H_2O $m^{-2}s^{-1}$) were determined on 12 and 19 August (2022) and 11 and 18 August (2023) between 10:00 and 13:00, respectively. On each vine, 3 replicates (three mature, healthy leaves between nodes 6-7 were analysed in each replicate), using a BioScientific ADC LCpro-SD portable photosynthesis system equipped with an infrared gas analyser. Leaves were enclosed in the chamber (under ambient conditions), held for 2 min for acclimation, then 5 readings per repetition were recorded at 1 minute intervals.

▪ *Yield components and berry composition*

The grapes were harvesting on the date of September 01, 2022 (DOY 244), respectively September 13 in 2023 (DOY 256).

At harvesting, for control and each experimental variant, determinations were made on quantitative (grape weight – grams, berry weight – grams, yield – kg/vine) and qualitative parameters (sugar content – ºBrix, titratable acidity – g/L tartaric acid). Sugar concentration in grapes was measured by using an Atago digital refractometer. The results were expresed in ºBrix. Titratable acidity was determined by titrating with 0.1 N NaOH using an Pellet digital biurette, and expresed as g/L tartaric acid.

Figure 1. Aspects from the plantation, following the application of treatments with kaolin and zeolite

Statistical analysis

Data were processed using Microsoft Excel (version 2010) and are shown as average values ± Standard Error (SE). The analysis of variance (ANOVA) was performed. Then, the post hoc Duncan Multiple Range Test (DMRT) by using IBM SPSS Statistics software was carried out to determine where there were statistically significant differences between different experimental variants or the periods. Statistically significant differences have been considered at the value of $p \leq 0.05$.

RESULTS AND DISCUSSIONS

Evolution of environmental conditions in years 2022 and 2023

Table 1 shows the evolution of the most important climate parameters for the experimental period (2022-2023) compared to the reference period (1991-2020), after the recommendations of National Meteorological Administration (Dima et al., 2019).

A careful analysis of them, during the two years of the study, showed that 2023 was a warmer and less rainy year than 2022. In particular, there were differences of 3.15°C in the case of average temperature in summer (VI-VIII), of 2.06°C for average temperature in the growing season (IV-X), of 1.62°C for average annual temperature, 1.4°C for average annual maximum temperature and 0.96°C for average temperature in the warmest month. At the same time, there was a decrease in precipitation during the vegetation period, by 64.5 mm in 2023, compared to 2022.

Comparing the average of the years in which the experience was carried out with the multiannual average over 30 years, it can be seen that all the values of the climatic parameters have registered large increases in the last two years, as follows: average annual temperature by 2.82ºC, average temperature in the growing season (IV-X) with 2.52ºC, average temperature in summer (VI-VIII) with 3.5ºC, average annual maximum temperature with 2.9ºC, average temperature in the warmest month with 3.16 ºC etc. Also noteworthy is the evolution of Tmax > 30°C and Tmax > 35°C where the number of days increased by 6 and 13 days, respectively, in favor of the last two years. The Huglin heliothermal index reached an average value of 3802 units during the experimental period, exceeding by 639 units the value recorded in the reference period, 1991-2020, respectively 3163, placing the area in ***the very warm climate class.***

Table 1. The main climatic parameters and bioclimatic indices during the experimentation period (2022-2023) compared to the reference period (1991-2020)

Climatic parameters and bioclimatic indices	Average	Years		Average
	1991-2020	2022	2023	2022-2023
Average annual temperature, ºC	10.98	12.99	14.61	13.80
Average temperature in the growing season (IV-X), ºC	17.46	18.95	21.01	19.98
Average temperature in summer (VI-VIII), ºC	22.15	24.07	27.22	25.65
Average annual maximum temperature, ºC	17.6	19.8	21.2	20.50
Average temperature in the warmest month, ºC	30.26	32.94	33.9	33.42
Average maximum temperature in summer (VI-VIII), ºC	29.68	32.03	32.86	32.45
Number of hot days (T_{max} > 30°C)	48	53	54	54
Number of very hot days (T_{max} > 35°C)	10	21	25	23
Annual total precipitation, mm	633	384	435	410
Total precipitation in the growing season (IV-X), mm	429.9	281.0	216.5	248.8
Total precipitation in summer (VI-VIII), mm	193.4	90.4	93.7	92.1
Hydrothermal coefficient (CH)	1.1	0.77	0.51	0.64
Huglin index (HI)	3163	3550	4054	3802
Winkler index (WI)	1762	1898	2356	2127
Cool night index (CI)	10.64	10.43	14.10	12.27

Values higher than 2400 units of the Huglin index lead to more unbalanced wines with higher alcohol concentration, sometimes over 13.5% vol. alcohol and the mandatory need for acidity corrections (Bucur et al., 2019).
This evolution of climate parameters confirms a series of researches carried out recently, which have highlighted the harmful effect of heat waves on the vine in the southern part of Romania (Mereanu, 2010; Bucur & Babeș, 2016, Bucur 2021), respectively, changes on the leaf apparatus and phenomena of wilting of the berries (Figures 2 and 3).
Hence the need to protect this perennial plant exposed to radiation and thermal stress.

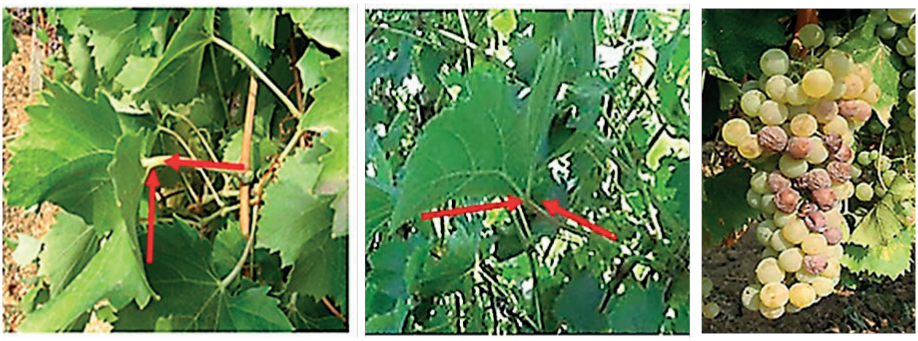

Figure 2. The change induced by heat waves, solar radiation and water stress on the angle of insertion of the limb of the leaf on the petiole (A) compared to the normal situation (B) and detail with sunburned berries, 26.08.2007 (after Mereanu, 2010)

Figure 3. Sunburn and wilting of the berries, after a summer heat wave registered in August 2022

Leaf gas exchange measurements
The obtained results as regard as of the leaf level gas exchanges and leaf water use efficiency are shown in Table 2. Analyzing the results obtained between the treatments applied on August 12, 2022, the photosynthesis intensity had the higher in the case ZEO 5% (13.85 μmol CO_2 m^{-2} s^{-1}), followed by KAO 5% (7.46 μmol CO_2 m^{-2} s^{-1}), respectively ZEO 3% (7.20 μmol CO_2 m^{-2} s^{-1}). Values are significantly lower between control, KAO 5% and ZEO 3%. The lowest photosynthesis rate has been registered for KAO 3% (3.29 μmol CO_2 m^{-2} s^{-1}), the differences being statistically significant as against KAO 5%, ZEO 3% and 5%; instead the differences are statistically insignificant if we compare with the control. And in the second determination, from August 19, 2022, the ZEO 5% variant reached the highest value (21.38 μmol CO_2 m^{-2} s^{-1}) for net photosynthesis. Significant differences in leaf photosynthesis rate during 2023 were found, for ZEO 5% (9.23 μmol CO_2 m^{-2} s^{-1}).
Regarding transpiration rate, the lowest values were recorded for the ZEO 3% variant (2.56 and 4.20 mmol H_2O m^{-2} s^{-1}) in 2022; respectively to the variants ZEO 3% (1.05 mmol H_2O m^{-2} s^{-1}) and KAO 5% (0.41 mmol H_2O m^{-2} s^{-1}), in the year 2023. Treatments with kaolin and zeolite applied in 2022 led to a decrease in

transpiration rate, compared to the control, in all experimental variants, which shows that the film distributed on the plant apparatus caused a decrease in the temperature of the leaves that lasted over time.

The treatment with zeolite in a concentration of 5%, which stood out for the highest values obtained by net photosynthesis, also reached increased values for transpiration rate; in this case the transport of water and mineral salts is more accentuated at higher values of the transpiration rate.

The synthetic water use efficiency (WUE) parameter recorded the highest values in 2022 for the zeolite treatments (3.24 - ZEO 5% and 5.09 - ZEO 3%), and in 2023 for the ZEO 3% variants - 8.19, respectively KAO 3% - 7.29.

Yield components and berry composition

Table 3 show to 'Fetească regală' berry composition among the treatments aplication (KAO 3%, KAO 5%, ZEO 3%, ZEO 5% and control) in terms of technological maturity (grape weight, berry weight, yield, sugar content and titrable acidity).

Grape weight and berry mean weight per vine was not significantly different between treatments, nor were yield. The drought conditions observed in this study limited the potential yield of the control, which was not different to experimental variants, treatments with kaolin and zeolite.

Regarding the accumulation of sugars in the berries, in the 2022 year of experimentation, a significant reduction in sugar content was found, on average from 26.37°Brix in the control, to 22.70°Brix in the ZEO 3% variant and 23.43°Brix for ZEO 5%. In 2023 there were no significant differences between the treatments in terms of the accumulation of sugars.

Table 2. The leaf net photosynthesis (A), transpiration intensity (E) and water use efficiency (WUE) during the 2022 and 2023 seasons to 'Fetească regală'

Treatment	12 August 2022	19 August 2022	11 August 2023	18 August 2023	Average treatment 1 (2022-2023)	Average treatment 2 (2022-2023)
A - Net photosynthesis (µmol CO_2 m^{-2} s^{-1})						
Control	6.25 ± 1.24 bcC	18.12 ± 1.68 aA	4.78 ± 0.09 bC	1.89 ± 0.98 aD	5.52 ± 0.66 bcC	10.00 ± 0.87 bcB
KAO 3%	3.29 ± 0.21 cC	13.71 ± 1.76 bA	4.47 ± 0.76 bC	4.65 ± 2.16 aC	3.88 ± 0.46 cC	9.18 ± 1.31 bcB
KAO 5%	7.46 ± 1.06 bB	12.61 ± 1.25 bA	4.74 ± 0.59 bC	1.55 ± 0.15 aD	6.10 ± 0.48 bcBC	7.08 ± 0.64 cBC
ZEO 3%	7.20 ± 0.04 bB	21.06 ± 0.36 aA	8.01 ± 0.72 aB	2.51 ± 0.38 aB	7.60 ± 0.34 bB	11.78 ± 0.14 abB
ZEO 5%	13.85 ± 1.82 aB	21.38 ± 1.52 aA	9.23 ± 1.17 aBC	5.21 ± 1.98 aC	11.54 ± 1.48 aB	13.30 ± 0.93 aB
E - Transpiration rate (mmol H_2O m^{-2} s^{-1})						
Control	4.80 ± 0.57 aB	5.75 ± 0.40 aA	1.55 ± 0.12 abBC	0.50 ± 0.22 aC	3.18 ± 0.24 aAB	3.17 ± 0.10 aAB
KAO 3%	3.00 ± 1.83 aAB	4.45 ± 0.39 aA	1.94 ± 0.41 abAB	1.11 ± 0.53 aB	2.47 ± 1.01 aAB	2.78 ± 0.25 aAB
KAO 5%	3.17 ± 0.62 aB	5.49 ± 0.49a A	1.70 ± 0.08 abC	0.41 ± 0.08 aD	2.44 ± 0.33 aBC	2.95 ± 0.28 aB
ZEO 3%	2.56 ± 0.74 aB	4.20 ± 0.38 aA	1.05 ± 0.24 bC	1.02 ± 0.43 aC	1.81 ± 0.30 aBC	2.61 ± 0.05 aB
ZEO 5%	4.60 ± 1.17 aAB	5.60 ± 0.45 aA	2.66 ± 0.47a BC	1.27 ± 0.78 aC	3.63 ± 0.82 aABC	3.43 ± 0.54 aBC
WUE - Water use efficiency (A/E)						
Control	1.47 ± 0.29 aB	3.52 ± 0.33 abAB	3.32 ± 0.28 bAB	3.75 ± 1.10 aA	2.39 ± 0.12 bAB	3.63 ± 0.57 abAB
KAO 3%	2.05 ± 0.78 aB	3.06 ± 0.14 bAB	2.36 ± 0.16 bB	7.29 ± 3.29 aA	2.20 ± 0.39 bB	5.17 ± 1.70 abAB
KAO 5%	2.49 ± 0.51 aA	2.37 ± 0.43 bA	2.76 ± 0.22 bA	4.29 ± 1.31 aA	2.63 ± 0.15 bA	3.33 ± 0.84 bA
ZEO 3%	3.23 ± 0.71 aB	5.09 ± 0.43 aB	8.19 ± 1.17 aA	4.96 ± 1.29 aB	5.71 ± 0.50 aB	5.03 ± 0.86 aB
ZEO 5%	3.24 ± 0.48 aB	3.87 ± 0.41 abAB	3.53 ± 0.21 bAB	6.24 ± 1.94 aA	3.38 ± 0.35 abAB	5.05 ± 1.04 aAB

Legend: KAO (Kaolin), ZEO (Zeolite). Data are shown as mean value ± SE (N = 3). The comparison was made by column between the different experimental variants and on the row between periods when physiological parameters were determined, by Duncan post-hoc Multiple Range Test (DMRT) by using IBM SPSS Statistics software. Statistically significant differences have been considered at the value of $p \leq 0.05$ and are represented by different letters (lowercase - comparison of experimental variants and uppercase - comparison of periods).

The accumulation of sugars in grape berries is influenced by several factors other than the climatic conditions during the ripening period of the grapes, namely: variety, the buds load attributed to pruning of vine, green work and operations applied and soil fertility.

Titratable acidity was maintained at normal values (6.6-6.9 g/L tartaric acid) in the case of treatments with kaolin 3% and 5%, but following the application of treatment with zeolite 5% the acidity took on a higher value (7.94 g/L tartaric acid), higher than the control.

Table 3. Yield parameter and grape components recorded in 'Fetească regală' treated with kaolin, zeolite and to the control vines in 2022 and 2023

Treatment	Grape weight (g)		Berry weight (g)		Yield (kg/vine)		Soluble solids (°Brix)		Total acidity (g/L tartaric acid)	
	2022	2023	2022	2023	2022	2023	2022	2023	2022	2023
Control	81.80 ± 3.73 a	91.09 ± 2.31 a	1.79 ± 0.07 b	1.60 ± 0.08 a	3.20 ± 0.19 a	2.88 ± 0.23 a	26.37 ± 0.15 a	22.83 ± 0.20 a	5.35 ± 0.19 a	6.15 ± 0.01 b
KAO 3%	71.15 ± 10.6 a	87.17 ± 3.42 a	1.84 ± 0.02 ab	1.78 ± 0.14 a	3.38 ± 0.19 a	2.50 ± 0.29 a	25.67 ± 0.23 b	22.17 ± 1.22 a	5.13 ± 0.1 a	6.95 ± 0.21 ab
KAO 5%	75.35 ± 6.92 a	83.95 ± 2.71 a	1.73 ± 0.07 b	1.63 ± 0.14 a	3.45 ± 0.11 a	2.81 ± 0.18 a	24.57 ± 0.18 c	21.27 ± 1.02 a	5.15 ± 0.28 a	6.99 ± 0.51 ab
ZEO 3%	78.00 ± 5.19 a	79.22 ± 6.69 a	1.88 ± 0.06 ab	1.44 ± 0.12 a	2.98 ± 0.11 a	2.55 ± 0.13 a	22.70 ± 0.31 e	21.87 ± 1.25 a	5.20 ± 0.07 a	6.41± 0.19 b
ZEO 5%	77.30 ± 7.38 a	86.92 ± 5.62 a	1.99 ± 0.06 a	1.66 ± 0.11 a	3.81 ± 0.46 a	2.63 ± 0.09 a	23.43 ± 0.12 d	21.17 ± 0.32 a	5.11 ± 0.07 a	7.94 ± 0.47 a

Legend: KAO (Kaolin), ZEO (Zeolite). Data are shown as mean value ± SE (N = 3). The comparison was done on columns between the different experimental variants, by the post hoc Duncan Multiple Range Test (DMRT) by using IBM SPSS Statistics software. Statistically significant differences have been considered at the value of $p \leq 0.05$ and are represented by letters lowercase.

CONCLUSIONS

Considering the future amplification of climate changes, with a negative influence on the vine, it is necessary to intervene with a series of mitigation measures in the short term, with immediate effect. Among these measures is the **application of sun protection substances**, with natural antiperspirant products based on clay (kaolin and zeolite).

The application of treatments with kaolin and zeolite in different concentrations (3 and 5%), at the beginning of the grape ripening phenophase, significantly improved photosynthesis and reduced the intensity of transpiration, which led to an intrinsic efficiency of water use in the vines in the field conditions at the time of the measurements.

Following the observations and determinations carried out over two years, the experimental variant ZEO 5% stood out, which recorded an increase in the rate of photosynthesis both in 2022 (13.85 µmol CO_2 m^{-2} s^{-1} August 12 and 21.38 µmol CO_2 m^{-2} s^{-1} August 19), but also in 2023 (9.23 µmol CO_2 m^{-2} s^{-1} August 11 and 5.21 µmol CO_2 m^{-2} s^{-1} August 18), compared to the control.

Regarding transpiration rate, the lowest values were recorded for the ZEO 3% variant (2.56 and 4.20 mmol H_2O m^{-2} s^{-1}) in 2022; respectively to the variants ZEO 3% (1.05 mmol H_2O m^{-2} s^{-1}) and KAO 5% (0.41 mmol H_2O m^{-2} s^{-1}), in the year 2023.

From an economic point of view, the application of these treatments does not require additional costs, compared to conventional technology, kaolin and zeolites are accessible materials, the use of which does not require equipment or expensive investments, and the spectrum of use is wider, ensuring phytosanitary protection.

The obtained results are of great interest, because they allow a better understanding of the effect of these antiperspirant treatments as a measure to protect the vine from radiation, thermal and water stress, with negative effects on the plant apparatus, its production and quality.

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