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Kaolin foliar application for the vineyard summer heat stress mitigation

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Abstract. In the context of ongoing climate change, this study aimed to evaluate the physiological and productive responses of two white grape cultivars, Carricante and Grillo, to the application of natural protective compound against excessive temperature and radiation. The trial was conducted during the summer 2023, in a commercial vineyard located on the Eastern slope of Mount Etna (Sicily island, south Italy). At the stage berries groat-size, vines were treated with kaolin (a white clay at 2%). A monthly monitoring was performed, until grape harvest, measuring leaf gas-exchanges and leaf water potential. At harvest, the yield and its traits were measured. Under Mediterranean stressed situation, the application of kaolin preserves the photosynthetic activity in the leaves and saves water, with different intensity depending on the cultivar. The ripening stage can be delayed with beneficial effect on maintaining higher level of titratable acidity and lower soluble solids accumulation. These latter finding is of practical interest in areas most subjected to global warming because counteract the berry shrivelling and the high concentration of the soluble solids in the grapes and consequently allows to obtain wines with low alcohol content, often preferred by the modern consumers. Finally, kaolin is easy to apply, quite cheap and very flexible since it can be used only if necessary, when the air temperature exceeds 35°C for at least 2-3 consecutive days.

1 Introduction

The Mediterranean region is one of the most important areas for grapevine cultivation according to its long history and high quality of wines. Cultivated varieties are closely related to different environments due to their adaptation along the centuries [1]. Recently, it has been found that in 2023 the global air temperature raised at 1.32 °C above pre-industrial level, which is very close to 1.5 °C higher limit established by Paris agreement on climate change [2]. This situation presumably will get worse in the futureand the development of a new strategy to preserve grape physiology, yield and grape composition should be evaluated. The Mediterranean region, characterized by a significant temperature increases and drought trends, is commonly considered as a “climate change hotspot” [3]. The effects of global warming on viticulture were reported by several authors and are represented by modifications of the phenological stages, misalignment between technological and phenolic maturity, acceleration of ripening process, increasing of the total soluble solids content and alteration of the biosynthesis of secondary metabolites [4]. Among the cultural practices useful for the mitigation of the climate change effects, the application of light-reflecting’ protectants, like kaolin (aluminium silicate), appears a valid strategy [5]. The effect of this natural clay is mainly physical and is based on its ability to increase albedo, as its white color, when applied to vine organs, reduces their temperature. Under water limitation, kaolin can maintain better net photosynthesis and transpiration rate, to avoid photosystem II efficiency loss and prevent leaf photoinhibition, chlorosis and necrosis [5, 6]. The goal of this study was to investigate the effects of kaolin spraying on physiology and productive responses in two white grapevine varieties, Carricante and Grillo, in a southernItaly environment characterized by lack of rains,high air temperature and solar radiations during the summer.

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2 Materials and methods

2.1 Sites description, plant material, experimental design and treatments

The research was carried out in 2023 in a vineyard located on the Eastern-facing slope of the Etna volcano, in Sicily Island (lat. 37°41'18.4" N; long. 15°09'24.2" E; elevation 252 m a.s.l.). Vines (Vitis vinifera L.) cvs. Carricante (CRR) and Grillo (GRL), both grafted onto 140 Ru rootstock, were planted 10 years ago, in rows orientated E-W, spaced 2.5 m between rows and 1.2 m within rows (3.330 vines/hectare). The vineyard was not irrigated. The cv. CRR was permanent cordon trained (vertical-shoot positioning) and vines were spur-pruned from six to eight nodes per vine (two nodes per spur and three to four spurs per vine). The training system adopted for vines of. GRL variety was Guyot. Two treatments have been studied: 1) control (only water spread); 2) Kaolin. The treatment with Kaolin was performed at BBCH73 berries groat-sized at the concentration of 20 g/L (2%). A completely randomized design has been adopted with three independent plots each containing three rows. All measurements were made on an index vine per block (9 readings per treatment). For each treatment and measurement date, physiological data were collected from nine fully exposed median leaves from main shoots [7]. The effects of treatments were monthly analysed from June to September 2023, at berries groat-size (BBCH 73), beginning of ripening (BBCH 81), berries developing colour (BBCH 83), berries ripe for harvest (BBCH 89) measuring the main physiological parameters and the vine water status (midday leaf water potential). Leaf temperature (Tleaf, °C), net photosynthesis (Pn, μmol CO_2 m^{-2} s^{-1}), transpiration rate (E, mmol CO_2 m^{-2} s^{-1}), and stomatal conductance (gs, mol CO_2 m^{-2} s^{-1}), were measured on well-exposed, median main leaves using a portable InfraRed Gas Analyser - ADC BioScientific Limited UK. Midday leaf water potential was measured by a Schöelander pressure chamber (Ecosearch Mod. 3100-SAPS). All measurements time was from 12:00 a.m. to 1.30 p.m. Monthly temperature and rainfall data were provided by the Sicilian Agrometeorological Service. At harvest, yield per vine and grape composition were analysed. For yield assessment, all bunches per target vine were counted and weighed, and production per vine was computed. Two bunches from each index vine (42 bunches) were randomly selected and dissected to determine mean berry weight. A 300-berry sample per experimental block was divided into three subsamples, crushed with a manual press, and free-run juice was utilized to determine the total soluble solids (TSS) with a digital refractometer with temperature correction (RX-5000 Atago Co., Ltd., Bellevue, WA, USA). MustTitratable acidity (TA, expressed as g/L of tartaric acid equivalents) and pH were performedusing an automatic titrator (Titrino Model 798, Metrohm, Riverview, FL, USA) with 5.0 mL juice samples being titrated against 0.1 M NaOH to pH 8.2 [8].

2.2 Statistical analyses

All data are shown as means ± standard error. Analysis of variance was performed with Statistica 6 software and, for each grape cultivar, difference between treatments were determined using the *t*-test at $p \leq 0.05$.

3 Results and Discussion

Meteorological data: Compared to the average data of the 2012-2022 interval, summer 2023 was marked by high daily maximum temperatures with peaks of 48.2 °C in July, 36.5 °C in August, 34.3 °C in September and 36.1 °C in July (Table 1). Total rainfall over the same period was very low, with only 92.5 mm against an average of 161.3 mm fall during the previous 11 years.

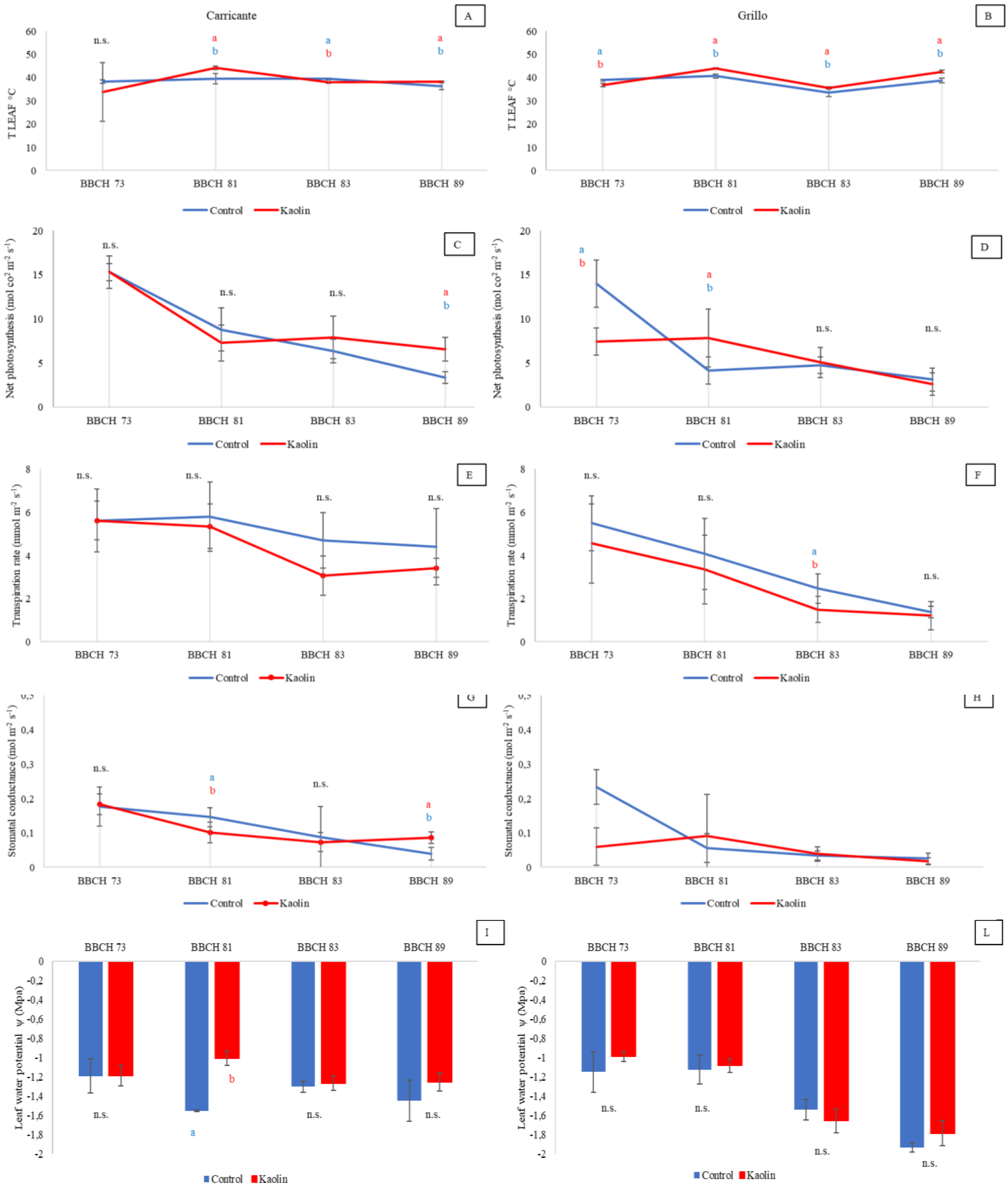
Physiological data: for both cultivars, kaolin application, generally speaking, did not modify the Pn during the 2023 summer, with exception for CRR vines which has shown a significant increase in Pn at BBCH 89 compared to untreated vines, whereas in cv. GRL a significant decrease in Pn was found a BBCH 73 and BBCH 81 (Figure 1C and D). As regardsErate, kaolin caused a general decrease with a halving of E values in both cultivars, especially during the last period of ripening (Figure 1 E and F). The effectof treatment on gs was instead less highlighted (Figure 1 G and H). These behaviours indicate that kaolin treated vines show a decrease in water consumption via transpiration process, without exercised a detrimental effect on CO2 fixation. As regards the leaf water potential, in cv. GRL no effect was observedin none of the 4 dates examined, whereas in cv. CRR a significant decrease was found in the medial leaves of treated vines compared to untreated ones at stage BBCH 81 (about -0.6 MPa), few days before the maximum temperatures registered (Figure 1 I and L), that is about 48 °C (Table 1). To note that, independently from cultivars, during the final period of grape ripening (BBCH 83 and 89), lower values of leaf water potential were found in cv. Grillo compared to cv. Carricante., with difference up to -0.5 MPa. This behaviour, together with a lower Pn and E values expressed during the same period, could indicate that cv. Grillo is more sensitive to summer stress conditions. However further and deeper investigations are needed. The abovementioned results were likely influenced by leaf temperature, which, in contrast to previous studies, was higher in kaolin-treated leaves on 5 of the 8 measurement dates (Figure 1A and B), likely due to reduced E and consequently lower thermoregulation.

Table 1 –Monthly minimum, mean and maximum air temperatures and rainfall registered in the experimental field in the last decade (2012-2022) and during 2023.

Month	Years 2012-2022				Year 2023			
	Tmax (°C)	Tmean (°C)	Tmin (°C)	Rain (mm)	Tmax (°C)	Tmean (°C)	Tmin (°C)	Rain (mm)
January	21.2	12.6	3.50	60.4	21.2	11.5	2.5	80.2
February	22.1	12.3	4.1	70.2	20.1	11.1	3.1	70.1
March	22.6	13.5	5.3	90.3	25.5	15.2	4.3	10.4
April	24.5	26.2	6.5	22.4	27.5	16.3	5.2	20.2
May	28.1	28.7	10.6	20.1	27.2	19.1	11.2	60.3
June	32.0	24.1	15.2	10.0	36.1	25.5	15.1	30.2
July	34.3	26.5	17.5	20.5	48.2	32.4	17.2	0.0
August	33.0	26.2	19.4	30.6	36.5	27.1	17.7	4.2
September	31.2	24.3	15.2	100.2	34.3	25.2	15.4	58.1

October	28.1	20.0	13.4	180.4	31.5	28.7	16.3	16.3
November	24.2	17.1	9.5	135.8	27.5	17.6	4.1	20.2
December	21.0	14.2	6.2	58.7	26.1	17.1	3.5	18.2

Figure 1 - Physiological parameters measured on main leaves of two grapevine cultivars during the growing season. Mean values for each data are reported ± S.E. (different letters indicate significant difference at $p \leq 0.05$ based on t-test, n.s. = not significant).



Data at harvest: with the same number of bunches per vine, in both cultivars no effect of kaolin treatment was found on yield, bunch and berry weight, number of berries per bunch and the fresh weight of the rachis (Table 2). At harvest, in the CRR vines, compared to untreated ones, kaolintreatment delayed grape ripening, as showed by lower total soluble solids (-1.2 °Brix) and higher titratable acidity (+1.58 g/L). The cv. GRL showed the same ripening behaviour of cv. CRR, but the soluble solids content did not change in comparison to untreated vines, probably because the yield per vine was more than halved with respect to CRR vines. In hot and dry environments, such as that of this study, the delay in the grape ripening is useful because if occurring during the cooler period, that is after August, the loss of malic acid and primary aroma compounds or aromatic precursors is reduced.

Table 2 - Influence of kaolin treatment on yield and quality parameters of grape in Carricante and Grillo. For each parameter and cultivar, mean values indicated by different letters are significantly different ($p \leq 0.05$, based on t-test).

Parameters	Carricante		Grillo	
	Kaolin	Control	Kaolin	Control
Yield/vine (kg)	2.09 ± 0.59	1.67 ± 0.57	0.80 ± 0.21	0.73 ± 0.11
Bunch/vine (n°)	10.6 ± 2.4	11.7 ± 3.9	7.2 ± 1.9	6.2 ± 1.0
Bunch weight (g)	197.2 ± 35	143.1 ± 37	110.2 ± 36	117.4 ± 19
Berry weight (g)	2.27 ± 0.21	2.03 ± 0.42	2.20 ± 0.46	1.98 ± 0.19
Berries/bunch (n.)	86.0 ± 25.9	72.1 ± 21.3	51.3 ± 28	58.0 ± 17
Rachis weight (g)	18.8 ± 2.7	13.5 ± 2.5	4.80 ± 2.5	5.30 ± 2.2
Total solublesolids (°Brix)	21.9 ± 0.16 b	23.1 ± 0,20 a	24.5 ± 0.31	23.9 ± 0.42
Titratableacidity (g/L)	5.87 ± 0.01 a	4.29 ± 0.21 b	5.66 ± 0.17 a	5.05 ± 0.55 b
Must pH	3.67 ± 0.01	3.58 ± 0.16	3.66 ± 0.17	3.54 ± 0.12

4 Conclusions

This study provides preliminary indications about physiological and productive behaviour of two white grapevine cultivar treated with kaolin in a very hot and dry environment in south Italy. Results suggest that under water stress conditions: (i) kaolin preserves leaf photosynthetic activity and reduces water loss, with cultivar-dependent effects; (ii) ripening is delayed, with beneficial effects on titratable acidity and soluble solids accumulation; and (iii) this effect is of practical interest in areas most affected by global warming, as it counteracts berry shrivelling and excessive sugar concentration, thereby enabling the production of wines with lower alcohol content, as increasingly demanded by modern consumers. Finally, kaolin is easy to apply, quite cheap, very flexible since it can be used only if necessary, that is when the air temperature exceeds 35°C for at least 2-3 consecutive days, and furthermore it provides a physical barrier against harmful organisms, especially insects.

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