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Research Article

A case study on the use of inter-row cover crops on a new and old vineyard cv. 'Assyrtiko' in Santorini Island

Efstratios Guillaume XYRAFIS[1]*, Elena KAZAKOU[2], Katerina BINIARI[1]

[1]*Agricultural University of Athens, Department of Crop Science, Laboratory of Viticulture, 75 Iera Odos Street, GR-11855 Athens, Greece; xyrafis@aua.gr (corresponding author); kbiniari@aua.gr*
[2]*CEFE, University of Montpellier, CNRS, EPHE, IRD, Institut Agro, Montpellier, France; elena.kazakou@cefe.cnrs.fr*

Abstract

In Santorini Island, Greece, the research and revival of cultivation techniques are crucial to the adaptation of viticulture in the current unique and extreme climatic and cultural conditions, including the increasingly extreme climatic phenomena resulting from climate change. This work presents the use of cover crops, in a new planting and productive Assyrtiko vineyard in Santorin Island. Our study is the first reflection of the use of cover crops in the special conditions of the island to mitigate wind and sandblasting damages and reduce high ground temperatures during days with high temperatures. We showed that the use of cover crops could play a significant role in reducing the wind speed and the resulting sandblasting that cause almost every year damage to young and productive vines when they are at critical growth stages.

Keywords: Assyrtiko; cover crops; Kladeftiko training system; Santorini Island

Introduction

The Mediterranean Basin is one of the regions most affected by climate change, with a severe decline of winter precipitations, setting strong limits on water resources especially for agriculture (Tuel and Eltahir, 2020). Traditionally, viticulture in this region has to cope with high temperatures, heat waves, strong winds, and droughts; these extreme conditions induce severe abiotic stress on plants and are expected to intensify due to climate change (Santos *et al*., 2003; Malheiro *et al*., 2010; Fraga *et al*., 2012).

Santorini, an island, located in South Aegean (Greece), has a Mediterranean climate, with mild winters, low rainfall, and cool spring seasons characterized by sea breezes from early May to the end of summer. Sea breezes occur during hot days, preventing fungal diseases from spreading on grapevines. Depending on the developmental stage of the vines, strong winds may be destructive to them, especially when they are in their early growth stages, resulting in yield losses and plant stresses. In the summer and near-harvest periods, the weather conditions are extreme, with high temperatures and heatwaves, which often occur during the summer and long drought periods. Due to climate change, the average annual temperature has been shown to have increased by approximately 3 °C in the last 45 years. Furthermore, a significant increase in the frequency of

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high-temperature days has been recorded, and bioclimatic indicators correspond to warmer climates, with warmer nights and higher droughts (Xyrafis *et al*., 2022).

The viticultural region of Santorini, Cyclades, Greece, is comprised of approximately 1000 ha ranging from sea level to terraces 150-350 m above sea level. In this ancient, arid, and phylloxera-free winegrowing region, two specific and unique training systems are used, which are well-adapted to the specific and extreme climate and weather conditions of the island, that is, the "kouloura", or basket shaped, and the "kladeftiko" (Xyrafis *et al*., 2021).

Adaptive measures must be planned and applied (Metzger *et al.,* 2011) to maintain the sustainability of the vineyard in the context of climate change, while several adaptation options have been reported for use in viticulture (Fraga *et al*., 2018; Koundouras *et al*., 2008; Duchene *et al*., 2012). A solution to mitigate the above effects is the use of interrow cover crops. Long-term usage of cover crops (vetch and barley) increases organic matter and nitrogen, prevent from soil erosion, reduce weeds, and lower soil temperature by maintaining soil moisture (Abad *et al*., 2021; Steenwerth and Guerra, 2012).

Santorini's vineyard is affected nearly annually by strong winds and by the consequential sandblasting in the spring when the vines are in a sensitive development stage. The above phenomenon can damage the vine inflorescences, shoots, and leaves (Figure 1). These effects can be reduced significantly by the use of interrow cover crops such as a mixture of *Hordeum vulgare* (barley) and *Vicia sativa* (vetch) in the vineyard (Figure 2). The use of these cover crops induces a significant reduction in wind speed and the avoidance of sandblasting, resulting in significantly reduced damage to early-development-stage vines.

Figure 1. Damages on flower clusters, leaves, and shoots caused by sand blasting and strong winds

Figure 2. Cover crops in a new planting and a productive vineyard of Assyrtiko

The objective of the experiment described here was a first attempt to evaluate the interrow use of cover crops on a vineyard trained with the traditional training system 'Kladeftiko' and a new planting of *Vitis vinifera* L. cv 'Assyrtiko' and to study the performance (temperature, leaf water potential, wind's speed reduction and

wind damage on vines) of each case in the semi-arid conditions of Santorini Island as an adaptive and sustainable alternative tool to other dry and warm wine regions.

Materials and Methods

Experimental design

We conducted a field experiment at a vineyard located in Oia village in Santorini Island (36.474223 N, 25.397511 E) during the period of 2021-2022. The experiment was run in two sequential trials. The trials evaluated cover crop performance on a 20 years old vineyard trained traditionally with 'kladeftiko' (KL) and a new planting (NP) of *Vitis vinifera* L. cv. Assyrtiko. A control was used for both treatments (CKL and CNP). Cover crops were applied interrow. The surface area for the KL was 1 ha and for the NP was 0.5 ha. The plant density for both cases was 2900 plants ha^{-1}. In the NP treatment, the cover crops were applied at each row, whereas in the KL case cover crops were applied row by row. *Hordeum vulgare* (barley) and *Vicia sativa* (vetch) were seeded inter-row in a mix of 50-50% with a density of 70 kg ha^{-1}. The mixture was sown in December of 2021. The weather conditions during our study are mentioned at Figure 3 (source: weather station of the National Observatory of Athens located in Fira, Santorini).

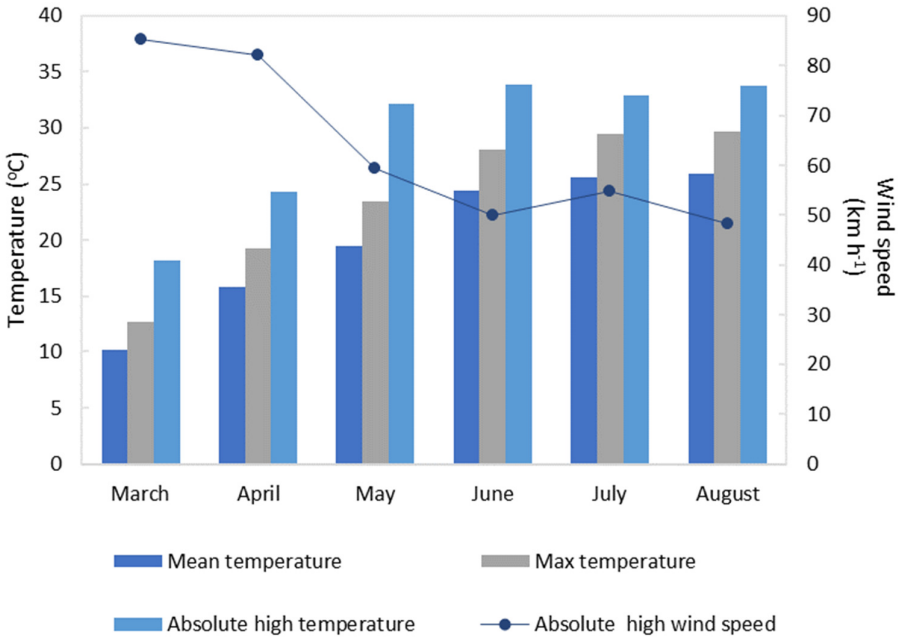

Figure 3. Weather data (mean, max, absolute high temperature and absolute high wind speed) of the studied region during the cultivation season of 2022

Wind speed, temperature, water potential and damage measurements

The trial was conducted using a randomized block design, with a block composed of 5 repetitions selected on each treatment. Wind speed was measured at grapes height during strong winds with a digital wind meter (PCE-A420, UK). At the end of April, when vines are at sensible developmental stages, strong winds and sandblasting happened causing significant damages. Those damages were estimated by counting damaged clusters and shoots of 20 plants per treatment. Leaves and ground temperatures were measured during a day with high temperatures with an infrared thermal camera (HT-02D KKMOON, China). During the season,

the Ψ leaf midday water potential was measured at bunch closure, veraison and harvest by a pressure chamber. Measurements were taken at sun zenith for Ψ leaf midday on five primary leaves per treatment, placed inside plastic bags.

Results

Wind and sandblasting measurements

The use of cover crops played a significant role in reducing the wind speed and sandblasting to the KL and NP vineyards at critical growth stage. We observed that during strong winds with gusts of 84 km h^{-1} at 14:00, the wind speed at plant height was limited to 28 km h^{-1} in the case of NP and 44 km h^{-1} in the case of KL (Figure 4).

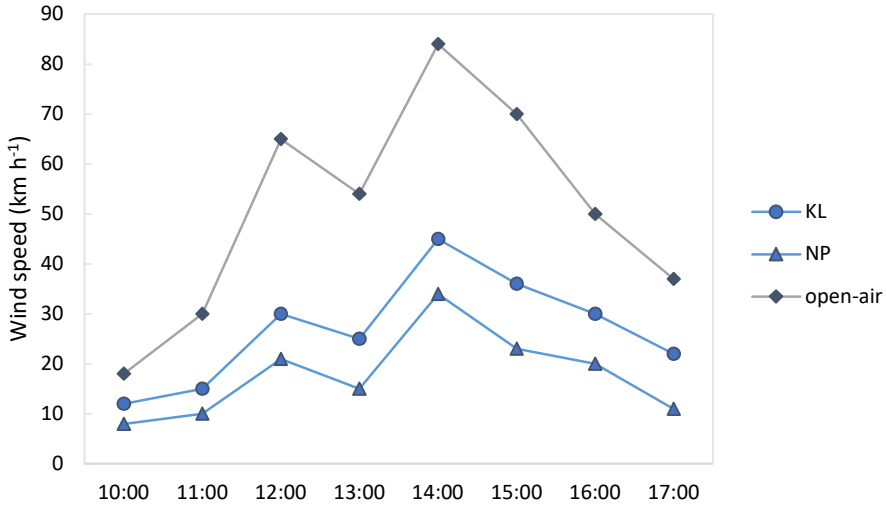

Figure 4. Wind speed evolution during a day with strong winds at the end of April 2022

Figure 5 shows the percentage of damages that have been occurred by strong winds, at end of April, on grapevines parts (clusters, shoots and leaves). Cover crops at the new plantings presented a damage of 5% on the leaves and shoots, compared to the control treatment where damage was 43%. In the case of KL, cover crops reduced damaged at 17%, of the leaves, shoots and clusters whereas in the control, the damage was 36%.

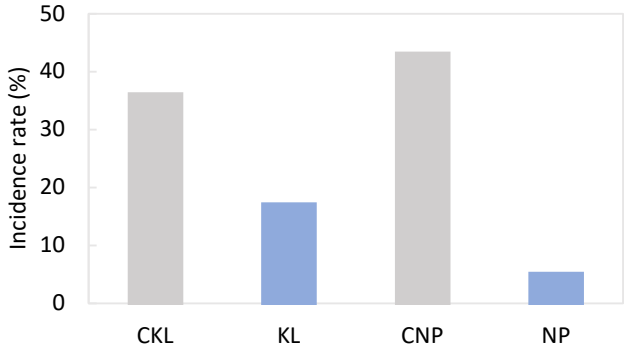

Figure 5. Damage % on different vine's parts during strong winds occurred in spring of 2022 on productive vines and new plantings with cover crops (KL and NP) and uncovered (CKL and CNP)

Temperature and water potential measurements

Figure 6 show the interow's ground temperatures during days with high temperatures, for both plots and both treatments. Specifically, the case of CKL showed a temperature of 52.1 ± 1.8 °C, while the temperature of KL decreased significantly at 28.1 ± 4 °C. Regarding the CNP, it has presented similar temperatures with CKL 54 ± 2.65 °C while the temperature of NP was significantly lower 30 ± 3 °C.

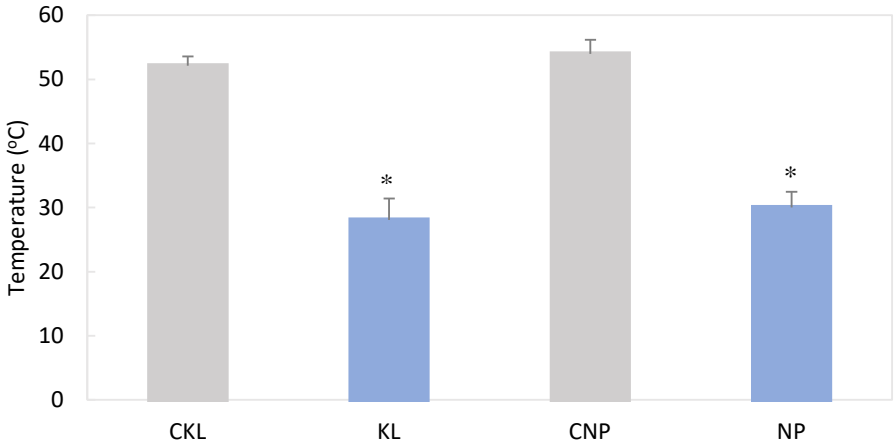

Figure 6. Inter-row ground temperature of uncovered rows (CKL and CNP) and rows with cover props (KL and NP) during summer middays with high temperatures for both training systems ('Kladeftiko' and new planting) of cv. 'Assyrtiko'. The values are averages ± SD. Averages followed by * are different $p < 0.05$, Tukey's HSD, n = 5.

There were no significant differences in vine water status between the two treatments for each developmental stage, however globally CKL always maintained a less stressed water status (i.e. less negative Ψ) (Figure 7). Specifically, we showed that the use of cover crops in the case of the KL has slightly increase water stress at the stage of bunch closure (-9.27 ± 0.67 MPa) of cv Assyrtiko with no significant differences from the control (-8.67 ± 0.57 MPa). During veraison Ψ midday was decreased for KL (-11.83 ± 0.59 MPa) in comparison to CKL (-9.76 ± 0.75). While at harvest the values were similar (~12.7 MPa).

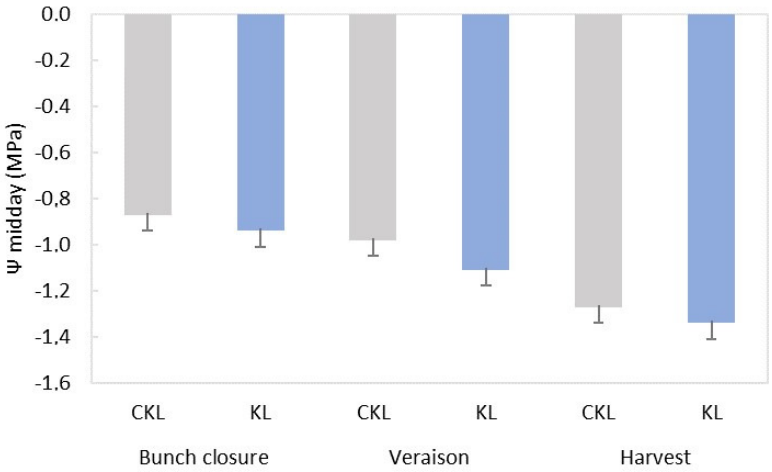

Figure 7. Leaf water potential Ψmidday (MPa) of vines with kladeftiko training system cv. Assyrtiko for both treatments CKL and KL during bunch closure, veraison and harvest. The values are averages ± SD. Averages followed by * are different $p < 0.05$, Tukey's HSD, n = 5.

Discussion

In this work we studied the use of cover crops in the arid region of Santorini Island in a new and a productive vineyard as a sustainable tool to mitigate the negative effects of the harsh winds and the resulted sandblasting which almost every year occur plant and yield damages. At the same time, we examined the effects of cover crops on the high seasonal ground temperatures and on the water potential of each vineyard case.

Strong winds and sandblasting are very common in the Mediterranean region, especially in the islands. Santorini's viticulture is an example where almost every year strong winds are causing significant damages on vine's organs and grapes. In 2022, damages were occurred by the spring's harsh winds and sandblasting and were recorded. The use of cover crops for both cases (KL and NP) has reduced the wind speed and gusts by 48% for the KL case and 67% for the NP while damages on shoots and clusters have been decreased 19% in the case of the KL and 38% in the case of the NP in comparison to the control treatment.

Regarding the ground temperature, we found that the interrow use of cover crops has significantly reduce the temperature by 43% for KL and NP during summer days with high temperatures. Our findings confirms that the cover crops reduce the daytime maximum temperature compared to no cover crops (Teasdale and Daughtry, 1993; Evans *et al*., 2016). On a daily basis, soils under cover crops can be cooler during the day and warmer during the night compared to soils without cover crops (Blanco and Ruis, 2020).

In general, cover crops result in an increase in water deficit, although this effect is highly variable as it depends on soil and climate characteristics, and on the period of the year in which the covers are active (Abad *et al.,* 2021). In our study we found that the use of cover crops has slightly increased the water stress at the KL during bunch closure, at veraison the use of cover crops presented a lower Ψ midday leaf while during harvest no differences were mentioned.

Conclusions

This work is the first reflection of the use of cover crops in the special conditions of the island of Santorini to mitigate wind and sandblasting damages and reduce high ground temperatures during days with high temperatures. However, repetition and further research are required in order to confirm our first-year results. It is important for Santorin's viticulture to identify practical alternatives and solutions that help to mitigate the effects of current and future climatic phenomena which will intensify due to climate change. Therefore, it is important to learn from traditional viticulture by looking for and reviving techniques that may benefit the viticulture of the region with respect to the authenticity and sustainability of each wine region.

Authors' Contributions

Conceptualization: EGX, EK. Methodology: EGX. Writing—review and editing: EGX, EK, KB. Supervision: EK, KB.

All authors read and approved the final manuscript.

Ethical approval (for researches involving animals or humans)

Not applicable.

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Conflict of Interests

The authors declare that there are no conflicts of interest related to this article.

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