Analysis of Cabernet Sauvignon and Aglianico responses to different pedo-climatic environments in southern Italy

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Keywords: Cabernet sauvignon, Aglianico, CWSI, SWAP, quality.

Abstract

Water deficit is one of the most important effects of climate change able to affect agricultural sectors. In general, it determines a reduction in biomass production, and for some plants, as in the case of grapevine, it can endorse fruit quality. The monitoring and management of plant water stress in the vineyard is critical as well as the knowledge of how each specific cultivars react to it. A multidisciplinary study was carried out to compare the Cabernet Sauvignon and Aglianico grapevine responses to different pedoclimatic conditions of southern Italy, in three areas devoted to high-quality wine production of Campania, Molise, and Sicilia regions. This study reports the preliminary results of the Italian National project "Influence of agro-climatic conditions on the microbiome and genetic expression of grapevines for the production of red wines: a multidisciplinary approach (ADAPT)". In each site, the environmental characteristics were described and the soils characterized through a pedological survey. During 2020-2021, soil water content and the principal weather variables (e.g., temperature, rainfall, solar radiation, etc.) have been monitored by means of in situ stations, while plant responses collected by means of field campaigns (LAI, LWP, grapes composition). The agro-hydrological model SWAP was used to solve the soil water balance in each site and to determine the Crop Water Stress Index (CWSI) from April to October in the years 2020 and 2021. The obtained CWSI index was compared with data collected on plant status (e.g., LWP) and correlated to grapes quality (e.g., sugar content, acidity) in each site. Finally, the potential CWSI of each experimental site was determined on reference and future IPCC climate scenarios RCP 4.5 and RCP 8.5 to classify the attitude to produce plant water stress of each site and the expected future evolution.

Introduction

In Mediterranean Regions, viticulture is one of the most important agricultural sector (Costa et al., 2016). Environmental conditions like soil and climate are key factors affecting grapevine productivity, grape and wine quality and the sensory attributes of wines (van Leeuwen & Seguin, 2006). Viticulture and wine production are largely done across regions with relatively dry climates, where the overall precipitation amount is critical factor in controlling soil water balance and plant water status, particularly in non irrigated vineyards (like in Italy). Severe dryness can also be problematic, especially during bud break to flowering, and if prolonged over the growing season may reduce grapevine growth, limit sugar development, and lower yields (Fraga, Malheiro, Moutinho-Pereiram, & Santos, 2013). In the last decades the problem of climate change has become crucial for many crops. In case of viticulture it could affect varieties distribution in different wine growing regions (Alonso & O'Neill, 2011; Battaglini, Barbeau, Bindi, & Badeck, 2009). Some world regions, such as Northern Europe, may benefit from climate change since it has demonstrated that the cultivation of grapevine varieties such as Merlot and Cabernet Franc could be performed at 50◦ Latitude North (Moriondo et al., 2013). Recently, Jones and Schultz (2016) examined potential latitudinal shifts due to climate change finding that many new regions are emerging due to the warming at higher latitudes, while existing cool climate regions are becoming more suitable as the climate evolves.

Specific viticultural techniques have been proposed by the experts to solve practically the problem. One of the proposed solutions is to choose late ripening varieties or clones, or the use of more vigorous rootstocks, increase the proportion of the use of autochthonous varieties, adaptation of training systems, irrigation or late pruning (Guti´errez- Gamboa, Liu, & Pszcz´olkowski, 2020; van Leeuwen et al., 2019). However, these solutions are not enough to mitigate the effects of global warming on viticulture. Thus, future planning requires a reliable assessment of the expected effects of climate change on both crop yield and quality through an integrated analysis of the components of different agricultural systems (e.g.soil, climate, plant), as can be performed properly by dynamic simulation modelling approaches (quantitative approaches) integrated with a quantitative approach (Land Evaluation, FAO, 1976) within a Hybrid Land Evaluation system (HLES), as suggested by Bonfante et al. (2018) that proposed a relative new approach to solve the challenge of climate change with an hybrid land evaluation system able to discriminate the attitude of a certain territory on the based on combining qualitative (standard Land Evaluation) and quantitative (simulation model) approaches. In detail, on the basis of the terroir concept and the role spatial interaction within the soil-plant-atmosphere system (SPA) has in grapes and wine quality, it is correct to think that expected climate change variability could concretely affect the resilience of terroirs within a viticultural district, with significant consequences for local farming communities.

This research reports the preliminary results of the Italian National project "Influence of agro-climatic conditions on the microbiome and genetic expression of grapevines for the production of red wines: a multidisciplinary approach (ADAPT)". In three Italian sites, the environmental characteristics were described and in addition soils proprieties were characterized through a pedological survey. Soil water content and the principal weather variables (e.g., temperature, rainfall, solar radiation, etc.) have been monitored by means of in situ stations, while plant responses collected by means of field campaigns (LAI, LWP, grapes composition) during the years 2020-2021. Then agro-hydrological model SWAP was used to solve the soil water balance in each site and to determine the Crop Water Stress Index (CWSI) from April to October in the years 2020 and 2021. The obtained CWSI index was compared with data collected on plant status (e.g., LWP) and correlated to grapes quality (e.g., sugar content, acidity) in each site. Finally, the potential CWSI of each experimental site was determined on reference and future IPCC climate scenarios RCP 4.5 and RCP 8.5 to classify the attitude to produce plant water stress of each site and the expected future evolution.

Materials and methods

The study was performed in three experimental farms located in Sothern Italy and exactly in Campania, Molise, and Sicily regions. In the selected farms a pedological survey was conducted to characterize the soils chemical and physics properties. In each farm were described two soils' profiles, one for each variety of grapevine (Aglianico and Cabernet Souvignon) and in correspondence of each horizon FDR probes (TERRASENSE SMT2) were fixed to monitor, during 2020 and 2021, soil water content. The monitoring was also done on the meteorological variables through weather stations (MeteoSense 4.0) that indicated temperature, radiation, rain, humidity, wind, etc. In addition, in correspondence to principal phenological stages of plants, biometrics and physiological measurements were done, such as Leaf Area Index (LAI) and Leaf Water Potential (LWP). Midday stem water potential was measured by a Schöelander pressure chamber (Soil Moisture Equipment Corp., Sta. Barbara, CA, USA) according to Matthews. Leaves were closed into a black hermetic plastic bag covered with an aluminum foil for at least two h before detachment from the vine and measurement. All measurements were made each year from DOY 181 (30th June) to DOY 248 (5th September) every 15 days from 12:00 a.m. to 1:30 p.m.

This monitored plant information was used in the agro-idrological model SWAP (Soil–Water–Atmosphere–Plant; Kroes et al.,2008) to solve the soil water balance with Richards equation (Richards, 1931), in order to calculate the CWSI for each soil identified as representative from the soil survey.

The applied daily crop water stress index (CWSI) was defined as
follows:

$$CWSI = 1 - \frac{Ta}{Tp} x\, 100$$

where Ta is the actual daily transpiration and Tp is the potential daily transpiration.

Once SWAP model was calibrated, it was applied to simulate the impacts of future climate scenarios using the high resolution regional climate model (RCM) COSMO-CLM (Rockel et al., 2008), with a configuration optimised over the Italian area employing at aspatial resolution of 0.0715°(about 8 km).
In particular, two different future climate scenarios RCP 4.5 and RCP 8.5 (Meinshausen et al., 2011) and Reference one (RC; 1971-2005), were applied.
In addition to the most and wine were done, the chemical analyses and spectrophotometric measurements of must and wine were done as follows: standard chemical analyses (soluble solids, total acidity, pH, total polyphenols (Folin-Ciocalteau Index) and Absorbances (Abs) were measured according to the OIV Compendium of International Methods of Analysis of Wine and Musts (OIV, 2016). Color intensity (CI) and hue were evaluated according to the Glories method (Vivas, 1998). Total anthocyanins were determined by the spectrophotometric method based on SO2 bleaching (Ribéreau-Gayon and Stonestreet, 1965). Tannins were determined according to Ribéreau-Gayon and Stonestreet (1965). Analyses were performed in duplicate using basic analytical equipment and a Shimadzu UV-1800 (Kyoto, Japan) UV spectrophotometer.

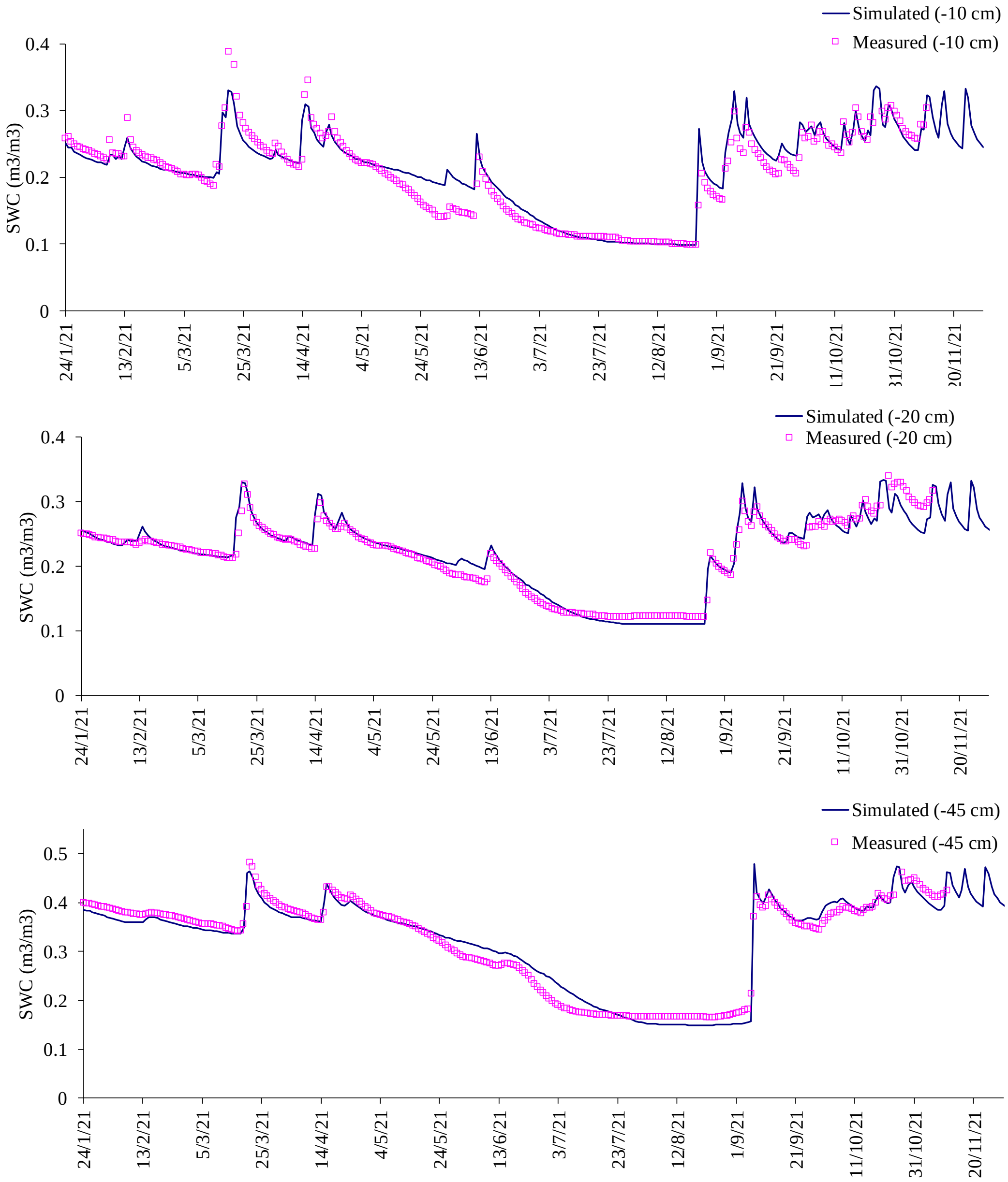

Figure 1. Model calibration: soil water content (SWC) measured vs simulated in one of the experimental farm (Sicilia) at two depths (-20 cm and -45 cm)

Results and discussion

Plant growth was similar between the two analysed cultivars in each site, with a maximum LAI value of 1.7 m^2m^{-2} (Molise site) in 2021. SWAP model has been calibrated and validated on two years of field measurements (soil water content at three different depths: e.g., -20, -45 and -65 cm; Figure 1), and the obtained results in terms of CWSI correlated to plant water status (LWP) monitored during the growing season (average R=0.7). Following, the results and discussion will be focused only on the Cabernet sauvignon cultivar.
The LWP, as well as the calculated CWSI, was positively correlated to some organoleptic grape characteristics: sugar content (R=0.9), tannins and polyphenols in seeds (both R=0.8), and total anthocyanins (R=0.7).
Among the experimental sites, the Sicilia represents the pedoclimatic condition where the Cabernet sauvignon cultivar suffer more water stress, while the Molise site the less.
The calibrated model was applied to determine the CWSI in the future climate scenarios (RCP4.5 and RCP8.5; 2010-2100) and the Reference one (RC; 1971-2005) (Fig. 2).
In the future climate change scenarios the highest monthly values of CWSI are principally realized in the last 30 years of the century (2070-100), with a high presence of cases with CWSI >80% in the RCP8.5.
Campania and Sicilia showed highest values of CWSI (Fig.2) that are realized during the grapes ripening period (August to September) with the maximum value in early September.

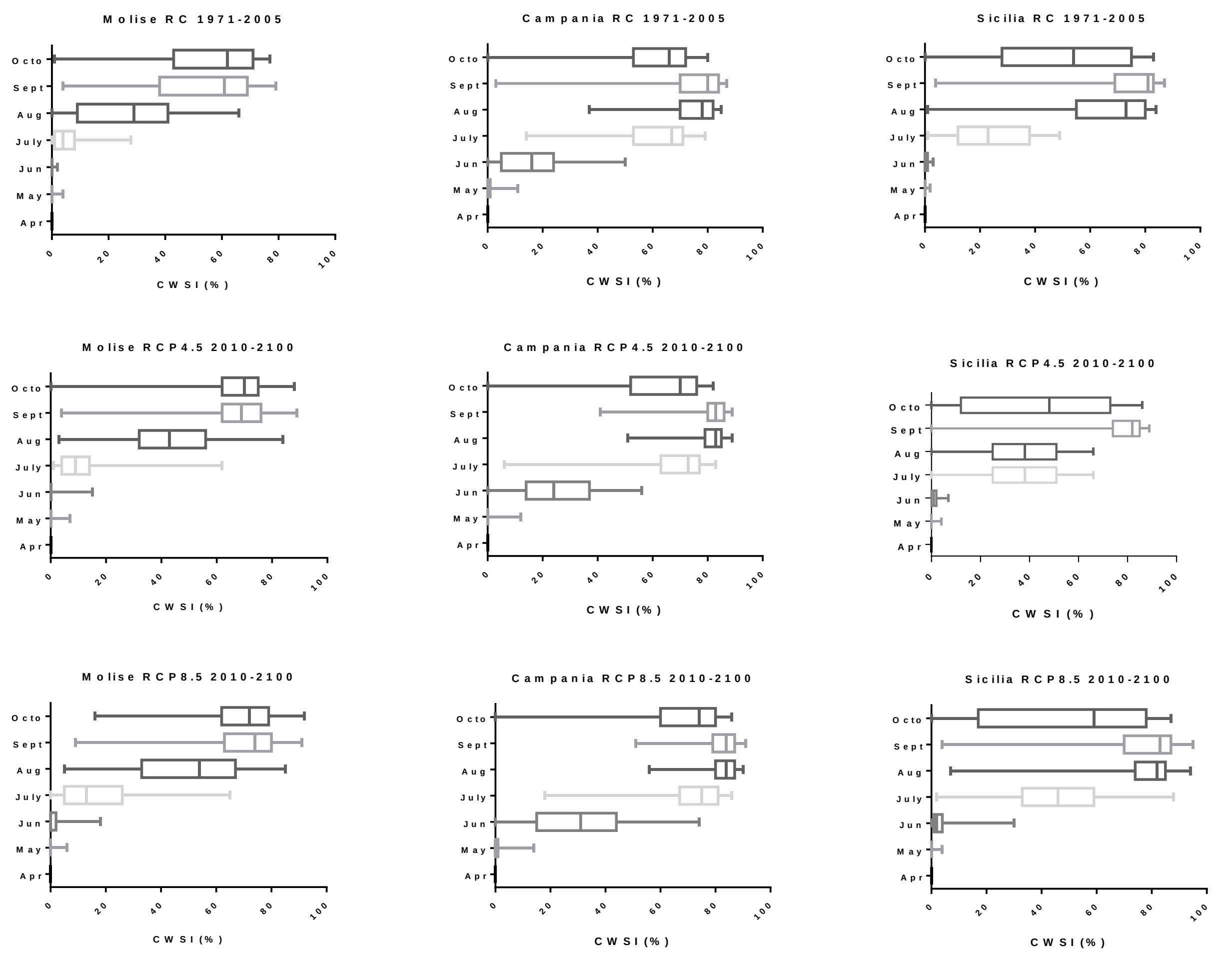

Figure 2. Monthly boxplot of CWSI (Crop Water Stress Index) in all experimental sites during the Reference Climate (RC; 1971-2005) and RCP 4.5 and 8.5 scenarios (2010-2100).

Conclusion

The work showed how a multidisciplinary approach and simulation modelling of SPA system application is able to identify the correlation between the site specific pedoclimatic characteristics and grape quality. This information allows performing simulations run under climate change scenarios and evaluating the impacts and the adaptation of the grapevine. In our experimental sites, the results confirm the simulation modeling potentiality in viticulture, underling the importance of correlations between CWSI and the main grapes' characteristics for CC impacts analysis.

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