Selcuk J Agr Food Sci, (2017) 31 (3), 52-57
ISSN: 2458-8377 DOI: 10.15316/SJAFS.2017.34

Selcuk Journal of Agriculture and Food Sciences

Variable Response of Leaf Temperature, Tissue Density and Greenness of 'Michele Palieri' (*Vitis vinifera* L.) Grapevines to Water Stress under Different Rootstock Effects

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ARTICLE INFO

Article history:
Received date: 13.06.2017
Accepted date: 27.07.2017

Keywords:
Drought stress
Leaf physiology
Deficit irrigation
Grapevine rootstock

ABSTRACT

Most vineyards around the world are established in regions exposed to seasonal drought where soil and atmospheric water deficits, together with high temperatures, exert large constraints on grapevines. Therefore, the increasing demand for vineyard irrigation requires an improvement in the efficiency of water use, such as deficit irrigation to allow plants withstand mild water stress. The present study was performed to reveal certain leaf physiological bases of grapevine responses to mild water deficits under various rootstock effects. Two irrigation levels (field capacity and 50% of field capacity) were applied to two years old vines of 'Michele Palieri' table grape cultivar, using 5 different rootstock, including own rooted vines. Investigations revealed that rootstocks have remarkable effects on leaf greenness (estimation of leaf chlorophyll content by SPAD meter readings) and slight effects on leaf temperature. Leaf tissue density also changed according to the rootstock use. Overall, deficit irrigation at 40% of field capacity may be a potential deficit irrigation program for grapevines when accurately optimized according to specific requirements of different grapevine genotypes.

1. Introduction

Majority of the vineyard regions are exposed to seasonal drought across the world. Water deficits become a limiting factor in grape production with an increase in aridity predicted in the near future according to global climate models (IPCC, 2007). Along with the irrigation water shortage, global warming is also negatively affecting the growth of grapevines. The negative impact of climate change has been indicated by changes in phenology and earlier harvests observed many part of the world (Jones and Davis, 2000; Webb et al., 2007). Studies have revealed that water shortage is also occurring in cool climate wine regions that exhibit special topography (van Leeuwen and Seguin 2006; Zsófi et al., 2009). Although, moderate water deficit is frequently recommended to promote the expression of high enological potential without altering yield in wine grapes, most vineyards for table grape production are seriously threatened by ever-increasing water shortage. Specifically, under the simultaneous influences of high evaporative demand (dry, warm air) and soil water deficit, plant tissues start dehydrating with detrimental impacts on production and berry quality (Jones et al., 2005; Deluc et al., 2009). The frequency of extreme heat wave and water shortage events such as heat waves are also predicted to increase, with negative effects on physiology, yield and quality of grapes. Although the vine develops certain physiological strategies, as illustrated in Fig. 1, to cope with moderate drought stress, excessive temperatures under drought conditions may lead to massive leaf shedding, with a consequent source–sink imbalance. These effects are unlikely to be uniform across the varieties and the rootstocks used (Schultz 2000; Jones et al., 2005). Experimental studies suggest that the constraints posed by climate change require adaptive management, namely irrigation to stabilize yield, maintaining or improving wine quality.

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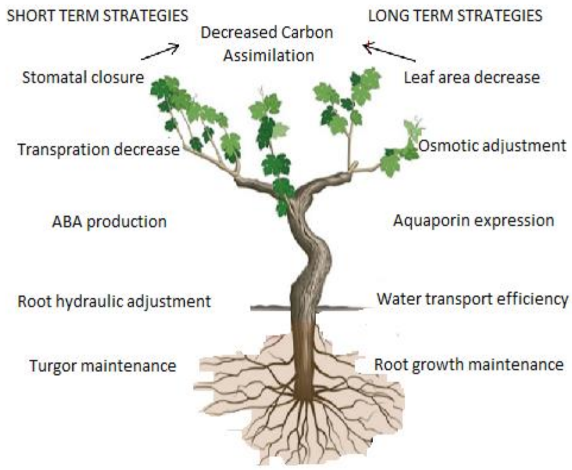

Fig. 1. Physiolocial responses of grapevines to water deficit

In order to prepare for the future, viticulture should adapt by efficient use of water while maintaining grape yield and quality. Vineyard establishment and management practices should be considered as valuable short-term solutions (Garcia de Cortazar Atauri 2006; Duchêne et al., 2010; Ripoche et al., 2010). But, additional strategies are needed, including the use of suitable plant material in cultivars and rootstocks. This necessitates a comprehensive and reliable knowledge of the physiological impacts of drought on grape yield and quality.

Plant traits determine the genotypic differences in performance under a given environmetal condition (Garnier and Navas 2012). In this regard, leaf growth and physiology are fundamental for ecosystem functioning, being related with important processes. Leaf parameters serve simple indicators of water stress since the leaves accurately respond to mild or moderate water deficit (Witkowski and Lamont 1991; Poorter et al., 2009; Pellegrino et al., 2005; Zufferey et al., 2011).

The present study was designed to reveal the seasonal changes of leaf temperature, tissue density and greenness (as indicator for chlorophyll content) in 'Michele Palieri' grapevines in response to deficit irrigation under relatively high air temperature conditioned in glasshouse.

2. Material and Method

The experiment was conducted during 2016 growing season at the experimental glasshouse in the Faculty of Agriculture, Selcuk University, Konya (Turkey). The study was conducted on two years old healthy vines of 'Michele Palieri' cultivar (Fig. 2). Two irrigation strategies [Full Irrigation (FI) and Deficit Irrigation (DI)] were applied to 'Michele Palieri' grapevines grafted on on Kober 5 BB (5 BB; *V. berlandieri* Planch. x *V. riparia* Michx.), Richter 99 (99 R; *V. riparia* Mich x *V. rupestris* Scheele), Richter 110 (110 R; *V. riparia* Mich x *V. rupestris* Scheele), 140 Ruggeri (140 Ru; *V. riparia* Mich x *V. rupestris* Scheele), 44-53 Malégue (44-53 M; *V. riparia* Mich x *V. rupestris* Scheele) or grown on own roots. Initially, two years old vines cultivated in equal sized pots (about 70 L in solid volume containing sterile peat and perlite). Experimental vines were selected on the basis of homogeneity in development. Irrigation treatments were replicated three times in randomized blocks, with two vines per replicate. The vines were placed in east-west oriented rows with the spaces 0.5 x 1 m. The vines were spur pruned to leave only the main shoot per plant. Cultivation practices were performed similar to the common practices of local growers. In canopy management, shoot positioning was done in vertical shoot positioned trellis system. The experimental vines received the same cultural practices such as weed control, and pruning and drip irrigation for a logical comparision of treatments. The shoots were tied with thread to wires 2.3 m above the pots to let plants grow on a perpendicular position to ensure equally benefiting from the sunlight (Sabir2013).

Fig. 2. A photo depicting the experimental glasshouse.

Irrigation treatments

Irrigations were programmed according to soil water matric potential (Ψm) levels using tensiometers (The Irrometer Company, Riverside, CA) placed at a depth of around 20 cm and approximately 12 cm from the trunk, and were continuously applied from bud break to the end of vegetation period. To verify the accuracy of tensiometers for monitoring soil moisture, field capacity levels of growth medium were calculated. For achieving this, two pots filled with known volume of oven-dried growth media for each group of vines were irrigated up to field capacity before imposing certain levels of soil moisture. To calculate the field capacity, the pots were put in the large plastic buckets and watered with known quantity of water and kept for 6 h to attain the field capacity. After six hours, the amount of the drained water in the bucket was measured and was subtracted from total amount of water applied initially (Satisha et al., 2006). The calculated value was considered as the amount of the irrigation water that has to be applied to attain 100% field capacity (FI). Fifty percent of FI was considered as DI (Sabirand Kara2010). In these conditions, tensiometers were employed for a more realistic expression of soil water depletion in terms of Ψm following the slightly modified procedure described by Myburgh and van der Walt (2005). Changes in Ψm were continuously recorded with daily readings at around 13:00 pm as well as before and after irrigations (Okamoto et al., 2004). Repeated readings during several days showed that the tensiometers readings at midday (13.00 pm) were constantly around 0.8-12 kPa (centibars) and 32-40 kPa for FI and DI conditions, respectively. For DI, irrigation was started when Ψm reached 40 kPa and was terminated when the calculated amount of water was applied to ensure 40% of field capacity. The start value of watering for FI group vines was adjusted to 12 kPa to ensure that the full water amount of field capacity was given. To ensure the uniformity of irrigation, the water was transported directly into the pots by micro-irrigation systems consisting of individual spaghetti tubes. Relatively higher air temperature in the glasshouse was kept to simulate the typical semi-arid Mediterranean climate. During vegetation period, daily air temperature was recorded with data logger (Ebro EBI 20 TH1) inside the glasshouse.

Measurements

The leaf temperatures (T_{leaf}) measurements were performed on twelve leaves (6th leaf of each main shoot) from twelve individual vines between 09:30 and 11:30 h (Sabir and Yazar 2015). Fully expanded but not senescent sun-exposed leaves at the outer canopy were selected for measurement in order to minimize the environmental effects (Greer and Weedon 2013). Similar area of the leaves were measured (Miranda et al. 2013), as instantaneous T_{leaf} can be non-uniform over such a large leaf. Approximate chlorophyll contents of leaves (the 3rd and 4th leaf at the shoot tips) were estimated by using portable chlorophyll meter (Minolta SPAD-502, Japan) and expressed as leaf greenness index (Uddling et al. 2007). Leaf tissue density (D) as (DM/FM) * 1000 (Bacelar et al. 2006).

Statistical analysis

A complete randomized block design with three replicates (consisted of four grafted vines) was established. Data were separately evaluated for each rootstock by analysis of variance (ANOVA) and treatment means were separated by Least Significant Differences (LSD) test at P < 0.05. Analysis was performed with SPSS program version 13.0 (SPSS Inc., Chicago, IL).

3. Results and Discussion

During hot summer days, midday air temperatures often exceed 35 °C are common around the viticulture region of Turkey. Therefore, in the present study, the inside air temperature of the experimental glasshouse was led to occur around 35±5.5 °C at midday by conditioning the during the vegetation period (Fig. 3). Long term extreme temperature stress has the chronic adverse effects on vine physiology and development. Such effects can vary according to conditions such as rootstock usage. By this study, changes in certain leaf physiological and tissue features of grafted or non-grafted vines of ‘Michele Palieri’ cultivar have been discussed with respect to water deficit.

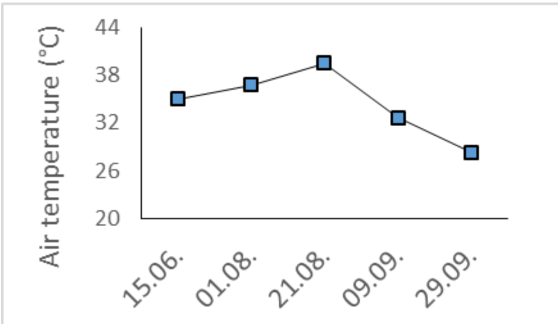

Fig 3. Midday maximum air temperature (°C) inside the experimental glasshouse at measurement times.

During the growth season, changes in leaf greenness (SPAD reading) of ‘Michele Palieri’ with respect to moderate water stress under different rootstock effects were depicted in Fig 4. At the beginning of the summer period, greenness values were similar between the irrigation levels irrespective of rootstocks. During the prolonged experimental period, significant differences occurred between the treatments. The increases in plant biomass accompanying with the air temperature rises in glasshouse may result in higher water demand, resulting the occurrence of such differences. For example, the leaf greenness was 12.5% higher in vines grafted on 99 R when subjected to DI. Similar, but lower, difference was also found in vines grafted on 110 R (8.6%). On the other hand, leaf greenness did not markedly change when 5 BB rootstock was used. The response of own rooted vines did not vary significantly with respect to irrigation water amount. The findings imply that the rootstocks generally affected the leaf greenness of grapevines subjected to different irrigation levels. Genotypic differences among various almond cultivars in response water deficit were also reported by Kester and Gradziel (1996) and Yadollahi et al. (2011). However, Flexas and Medrano (2002) reported that water stress always reduces leaf greenness in C3 plants leaves because of chlorophyll degradation.

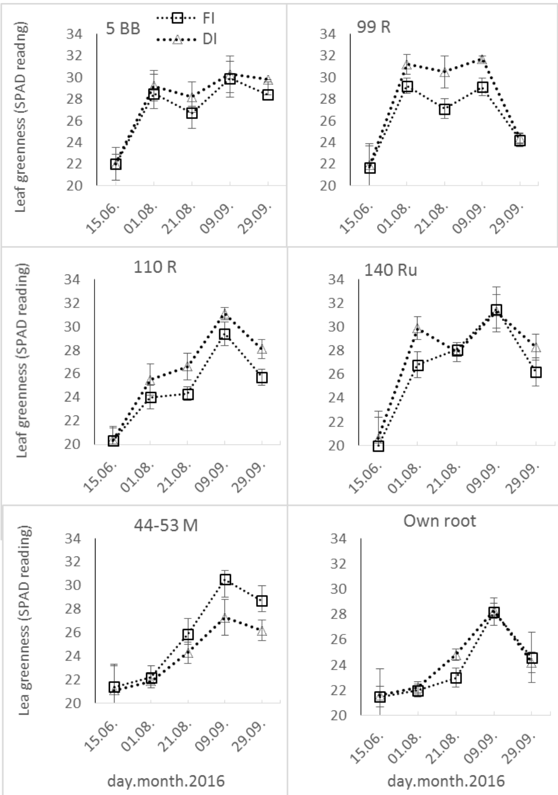

Fig 4. Changes in leaf greenness (SPAD reading) of 'Michele Palieri' with respect to moderate water stress under different rootstock effects. (FI: Full Irrigation, DI: Deficit Irrigation). Error bars represent standard errors.

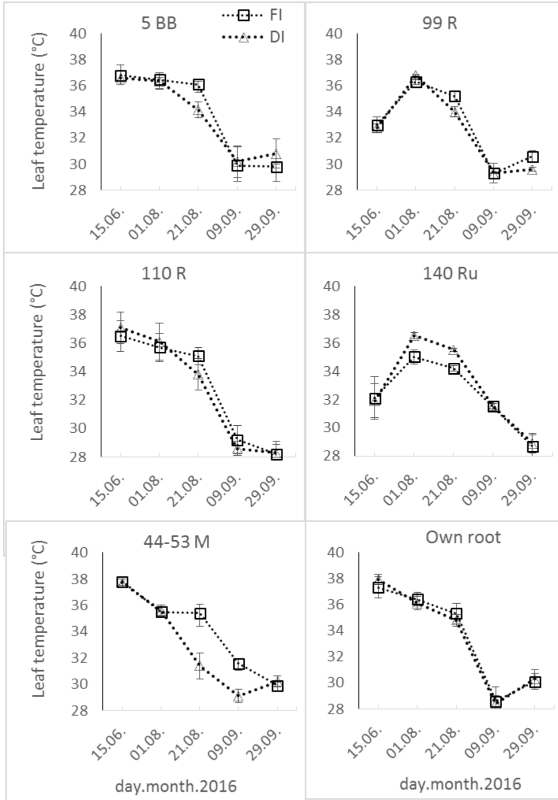

Fig 5. Changes in leaf temperature (°C) of 'Michele Palieri' with respect to moderate water stress under different rootstock effects. (FI: Full Irrigation, DI: Deficit Irrigation). Error bars represent standard errors.

Considering the findings shown in Fig 5, it can be stated that leaf temperature response of 'Michele Palieri' grapevines did not display great alteration in response to DI, except for certain fluctuations. The initial leaf temperature values were between 32.8 C (DI treated vines on 99 R) and 37.8 C (FI treated vines on 44-53 M). Leaf temperature values between the irrigation treatments were similar until the midseason (01.08.2017) and afterwards it was higher in DI vines grafted on 5 BB and 44-53 M. Later, the leaf temperature tended to draw similar course between the treatments. Studying on the effects of irrigation water deficit on olive trees cultivated under Mediterranean environmental condition, Pliakoni and Nanos (2011) concluded that leaf temperature were similar soon after treatment initiation (July) and after the 1-month deficit period (August).

On the other hand, it should be underlined that although the air temperature was at the highest level of vegetation period at around 21.08.2017, overall leaf temperature values were in decrease tendency. This finding suggest the general knowledge on the adaptive strategies of most *Vitis* spp. genotypes to environmental stress conditions, including the water shortage during the arid season (Chaves et al. 2010).

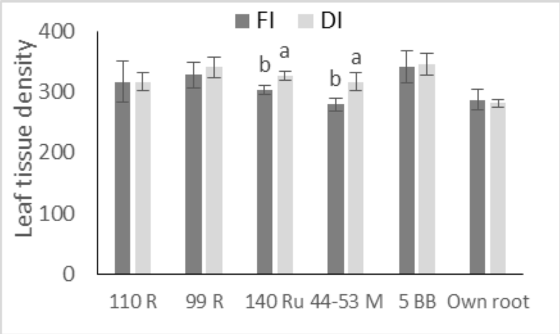

Fig 6. Changes in leaf tissue density (mg g^{-1}) of 'Michele Palieri' with respect to moderate water stress under different rootstock effects. (FI: Full Irrigation, DI: Deficit Irrigation). Values of bars indicated by different letters identify significantly different groups ($P<0.05$, LSD test). Error bars represent standard errors.

Rootstocks differently affected the leaf tissue density of 'Michele Palieri' grapevines subjected to different irrigation levels (Fig. 6). Leaf tissue density values of vines subjected to DI were significantly higher than those of FI when grafted on 140 Ru or 4453 M. It is well-known that more rigid cell walls may develop under prolonged water deficits (Chaves et al., 2010), affecting the transpiration rate and water statutes of tissues. Alteration of leaf temperature in vines grafted on 140 Ru and 4453 M may be related to differences of tissue density resulting from DI treatment. Leaf morpho-anatomy and related biochemistry (epicuticular wax composition, lipid composition, mesophyll thickness, etc.) play a significant role in explaining plant adaptation to water stress (Boyer et al., 1997; Cameron et al., 2006). Significant differences among *V. vinifera* have been reported in these characteristics (Moutinho-Pereira et al., 2007). Grapevine is generally considered a 'drought-avoiding' species, with an efficient stomatal control over transpiration (Schultz 2003).

Correlation between leaf temperature and leaf greenness was depicted in Fig 7. The pooled data on these parameters revealed that there was significant negative correlation between leaf temperature and leaf greenness. Reductions in leaf temperature were closely associated with higher leaf greenness. Lighter leaf color contributed to increased leaf temperature. Ability of plants to provide cooling in the urban environment is increasingly recognized.

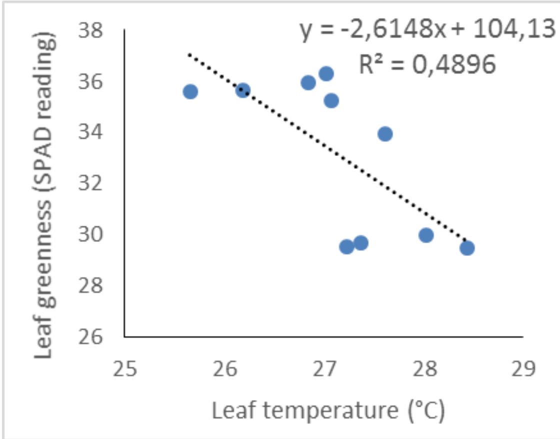

Fig 7. Correlation between leaf greenness and leaf temperature

Plants use various mechanisms to regulate leaf temperature one of which, probably, may be related with leaf color regulation. Certain leaf traits and physiological processes can influence the amount of radiation absorbed by the leaf and how the absorbed heat is later dissipated. Leaves, however, exhibit these multiple traits simultaneously. Therefore, the relative contribution of multiple traits to leaf temperature regulation, and how do they rank in significance, in various types of leaves, is still not well-understood.

4. Conclusion

Scarcity of irrigation water in the Mediterranean Region urges the scientists for the improvement of methods to reduce water use for agricultural production. Deficit irrigation could potentially result in water savings in the extensively cultivated grapevines. But the level of water supply for deficit irrigation should be accurately calculated with careful considerations on several factors such as scion genotype, rootstock, soil or climate characteristics. Preliminary results of the present investigations imply that deficit irrigation at 50% of field capacity may be a potential deficit irrigation program for grapevines. Nonetheless, future studies with comprehensive investigations will shed light into specific requirements of different grapevine genotypes.

Acknowledement

This study was generated from the Master Thesis of Zekiye Sahin. The authors wish to thank Scientific Research Project Coordination Unit (BAP) of Selcuk University for the financial support (Project No: 17201062).

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