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ORIGINAL ARTICLE

The Response of Soilless Grown 'Michele Palieri' (*Vitis vinifera* L.) Grapevine Cultivar to Deficit Irrigation Under the Effects of Different Rootstocks

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Abstract
Global warming, altering the physiology and irrigation demand of grapevines, has already been perceived in certain premium viticulture regions across the world. Selection of proper rootstocks for especially new cultivars has vital role for a sustainable viticulture under water-deficit conditions. The grapevine cultivar 'Michele Palieri' has been finding a good reception on the global markets. The objective of this study was to determine the response of 'Michele Palieri' cultivar to deficit irrigation using different rootstocks with distinct genetic origins. Two irrigation regimes (Full Irrigation [FI] and Deficit Irrigation [DI]) were applied to the vines of different grafting combinations of 'Michele Palieri' with Kober 5 BB, Richter 99, Richter 110, 140 Ruggeri, 44–53 Malégue or grown on own roots. Two years old vines were cultivated in 60 L pots containing sterile peat under controlled glasshouse conditions. Irrigations were regulated according to soil water matric potential (Ψm) levels using tensiometers. The volume of the irrigation water that has to be applied to attain 100% field capacity was performed as FI, while 50% of FI was considered as DI. The water was transported directly into the pots by micro-irrigation systems consisting of individual spaghetti tubes. The vines of DI treatment showed visible symptoms of mild water stress (e.g., loss of turgor in shoot tips), but no defoliation or leaf necrosis occurred. DI treatment reduced the gs of 'Michele Palieri' scion cultivar in varying levels depending on the rootstock. DI treatment also affected vegetative growth of the scion cultivar in different levels. For example, the greatest decrease (26.7%) in shoot length resulting from DI was determined in 'Michele Palieri'/5 BB grapevines, followed by own rooted vines (13.1%), while the lowest change (2.4%) was found in vines grafted on 110 R. Overall findings of this study imply that the rootstocks originating from *V. berlandiery* × *V. rupestris* hybrids (110 R, 99 R, 140 Ru and 44–53 M) better performed in a similar genetic aptitude under deficit irrigation regime while the rootstock 5 BB (*V. berlandiery* × *V. rupestris*) showed more susceptible responses. On the other hand, the general response of own rooted vines were better than those grafted on 5 BB. Therefore, the use of one of *V. berlandiery* × *V. rupestris* hybrids may be a better choice for viticulture under semiarid regions.

Keywords 'Michele Palieri' grapes · Rootstock · Water shortage · Deficit irrigation

Die Reaktion auf Trockenstress bei der erdelos kultivierten Traubensorte 'Michele Palieri' (*Vitis vinifera* L.) auf verschiedenen Unterlagen

Schlüsselwörter 'Michele Palieri' · Traubensorte · Unterlage · Wassermangel · Trockenstress

Introduction

Anthropogenic and climate changes have been causing new pressures on global water resources (Vörösmarty et al. 2000). Around the world, vineyards are generally located in regions with a risk of drought and high temperature that constitute serious constraints on grape yield and quality. It is also believed that the frequency of extreme events such as heat waves or global warming is predicted to increase

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(Kuster et al. 2013). High temperature accompanying with water deficit during berry development exert a negative effect on berry composition and subsequent wine quality (Sadras and Moran 2012). Studies revealed that warming and water shortage alter the balance of berry sensory features through acceleration of mesocarp cell death and berry shriveling (Bonada et al. 2013). The effects of global warming are now perceived in 27 premium viticulture regions across the globe with an average 1.3 °C warming of the growing season from 1950 to 2000. Further, the outlook over the next 50 years projects a 2 °C average warming (Jones 2012). Growing season temperatures in Europe have increased by 1.7 °C from 1950 to 2004 (Duchene and Schneider 2005; Fraga et al. 2012). As stated by Palliotti et al. (2014), such change in climate may induce increased heat summations, altered vine phenology, changes in soil fertility and irrigation demand. Short and long term solutions to mitigate climate change effects and related stresses such as drought and heat, save water and minimize environmental burdens of viticulture. To achieve this the solutions, for example, include (1) selection of concrete scion/rootstock graft combination, (2) scheduling of more precise irrigation, (3) use of protected cultivation (soil mulching, plastic cover), (4) maintenance of proper operations in general cultivation techniques (Padgett-Johnson et al. 2000; Satisha et al. 2006). The correct placement of a given grape variety is nowadays depending not just on the need to match its thermal requirement, yet also to rationalize the use of natural resources, mainly water. Therefore, it assumes particular importance the study of the adaptability of varieties to multiple summer stresses and the identification of resistant genotypes, namely those showing high water use efficiency, for cultivation in environments characterized by high thermal and radiative regimes and low rainfall.

Rootstock usage in grape production has already become a common practice worldwide, due to the endemic pathogen *Daktulosphaira vitifoliae* F. (phylloxera), including the presence of nematodes and pests, high salinity or active lime (Dry 2007). Commercial rootstocks used over the world, are hybrids of the species *Vitis berlandieri, V. riparia*, or *V. rupestris* to control phylloxera damage (Serra et al. 2013). Drought tolerance has become essential for arid and semi-arid areas that have been experiencing summer drought with increasing frequency over the last years. The situation becomes more problematic in areas characterized by temperate, tropical or Mediterranean type climates, namely the southern Mediterranean Europe, Turkey, the northeast of Brazil, the central and southern India, or the western part of Australia (Satisha et al. 2006; Teixeira et al. 2014; García-Tejero et al. 2014). Therefore, in these regions table grape is usually grown under irrigated conditions (Tarricone et al. 2012). Due to high degree of genetic variability (Sabir et al. 2010), selection of concrete rootstock necessitates comprehensive considerations in every aspect of agricultural factors to ensure adequate productivity for long time. Determination of favorable rootstock varieties for certain purposes can be based on an array of criteria such as soil attributes (chemistry, texture, drought and lime content), rooting ability usefulness in grafting, scion/stock compatibility and genetic potential in vine vigor. Studies demonstrated that selection of proper rootstocks under water-deficit conditions has vital role for a sustainable viticulture under drought conditions (Ezzahouani and Williams 1995; Padgett-Johnson et al. 2000; Satisha et al. 2006; Merli et al. 2016).

The grapevine cultivar 'Michele Palieri', crossing 'Alphonse Lavallée' × 'Red Malaga', is finding a good reception on the global markets mainly because of its black-violet berry color, good storage and resistance to transport. However, interestingly there is insufficient experimental data on rootstock effect on growth and/or physiological features of such a world widely popular table grape variety. Thus, the objective of the present study was to determine the response of soilless grown 'Michele Palieri' grapevine cultivar to deficit irrigation on different rootstocks coming from different genetic origins.

Materials and Methods

Experimental Layout and Growth Condition

Trials were performed in the research and implementation glasshouse of Selcuk University, Konya, Turkey. The 'Michele Palieri' grapevine cultivar is one of the most important table grape cultivars known worldwide. The experimental layout was a randomized complete block design with two irrigation (Full Irrigation [FI] and Deficit Irrigation [DI]) and different grafting combinations of 'Michele Palieri' on Kober 5 BB (5 BB; *V. berlandieri* Planch. × *V. riparia* Michx.), Richter 99 (99 R; *V. riparia* Mich × *V. rupestris* Scheele), Richter 110 (110 R; *V. riparia* Mich × *V. rupestris* Scheele), 140 Ruggeri (140 Ru; *V. riparia* Mich × *V. rupestris* Scheele), 44–53 Malégue (44–53 M; *V. riparia* Mich × *V. rupestris* Scheele) or grown on own roots. At the beginning of the vegetation period, two years old vines grown in equalsized pots were selected on the basis of homogeneity in vegetative development. Irrigation treatments were replicated three times in randomized blocks, with two vines per replicate. Vines were grown under controlled glasshouse conditions. The vines were individually cultivated in 60 L (solid volume) pots containing sterile peat (1.034% N, 0.94% P_2O_5, 0.64% K_2O, pH 5.88, Klasman®) and perlite (0–3 mm in diameter) mixture in equal volume. The pots were isolated from the ground with plastic sheets. The vines were spur pruned to leave only the single bud (one main shoot) per plant. 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 (Sabir 2013). All the vines received the same annual amount of fertilizer (approx. 15 g N, 10 g P, 15 g K) from April to August.

Achieving the Irrigation Regimes

Irrigations were regulated according to soil water matric potential (Ψm) levels using tensiometers (The Irrometer Company, Riverside, CA) placed at a depth of 20 cm and approximately 12 cm from the trunk, and were continuously applied from bud break (March) to the end of vegetation period (beginning of October). Field capacity levels were calculated to verify the accuracy of tensiometers for monitoring soil moisture. For this, two randomly taken pots filled with known volume of oven-dried growth media for each group of vines were irrigated up to field capacity before imposing different levels of soil moisture. To calculate the field capacity, the pots were placed in the large plastic buckets and irrigated 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 volume of the irrigation water that has to be applied to attain 100% field capacity (FI). Fifty percent of FI was considered as DI (Sabir and Kara 2010). 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 50% 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 and relative humidity, recorded using data logger (Ebro EBI 20 TH1) inside the glasshouse, were 18–35 °C and 32–65%, respectively. In the hot and dry days, excessive heat accumulation in glasshouse was avoided by opening the roof and sidewall windows as well as slight whitewash painting (providing approx. 20–30% light reflection) to keep shoot tips and young leaves from burning. Under this condition, the instantaneous daylight intensity inside the glasshouse was between 60,400 and 74,600 lx (Lutron LX-105) at around 13:00 pm.

Measurements

The stomatal conductance (gs) measurements were made on the 6th leaf of the shoot tip from each individual vines from 09:30 to 11:30 h (Sabir and Yazar 2015). Fully expanded but not senescent sunlit leaves at the outer canopy were chosen for measurement (Johnson et al. 2009). As previously described by Düring and Loveys (1996) and Stavrinides et al. (2010), gs was measured near the central vein of the leaf blade with a steady state porometer (SC-1 Leaf Porometer) (Zufferey et al. 2011) and was expressed as mmol $H_2O\,m^{-2}\,s^{-1}$. The same area of the leaves were measured (Miranda et al. 2013), because instantaneous gs can be nonuniform over such a large leaf. Instantaneous air temperature, air humidity (using mobile data logger EBRO EBI 20) and light intensity (using light meter Lutron LX-105) inside the experimental glasshouse were recorded to tract growth condition of experimental grapevines (Hirayama et al. 2006). The recordings were read with the software Winlog-Basic. Measurements on shoot length (scion shoot was measured with a sensitivity of 1 mm), and shoot diameter (measured by digital compass at a point 1 cm above the second node). Pruning weight (g/plant) was recorded as a measure of vine vigour in dormant season following the vegetation period of the experimental year (Sabir 2013).

Statistical Analysis

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

Results

As illustrated in Fig. 1, the rootstock markedly affected the gs values of 'Michele Palieri' scion cultivar. At the beginning of the summer period (15.06.2016), there were no significant differences for the gs values among the irrigation treatments. However, the gs at this date exhibited great variation changing from the lowest value of 247.2 mmol

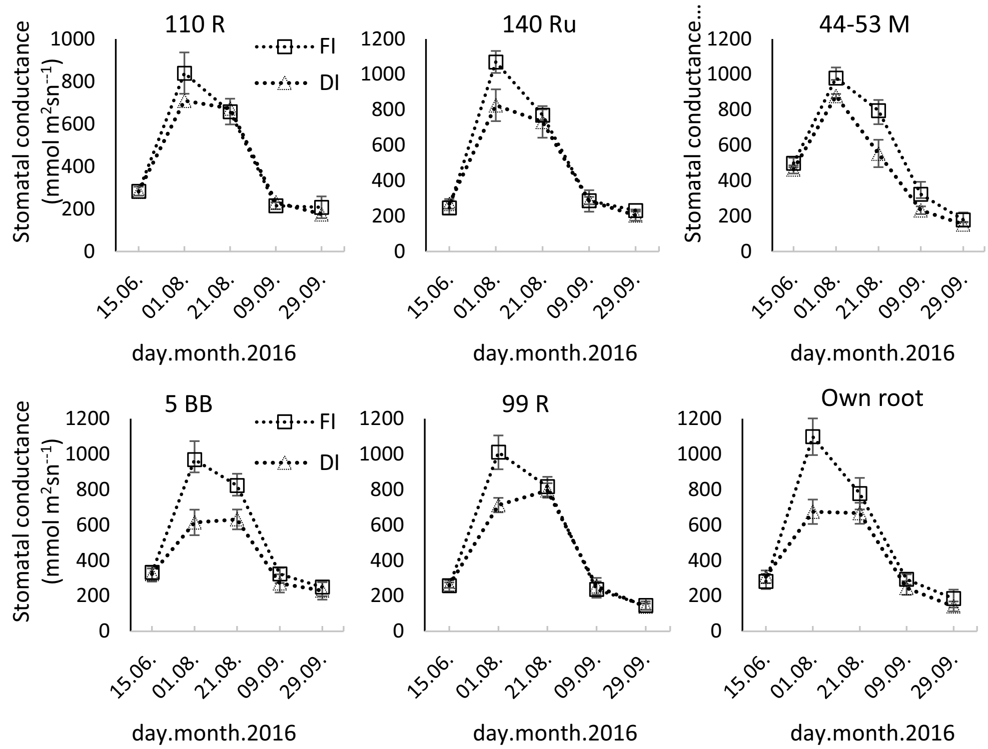

Fig. 1 Seasonal changes in stomatal conductance of 'Michele Palieri' grapevines grafted on different rootstocks in response to different irrigation treatments. Each bar represents the mean ± standard error

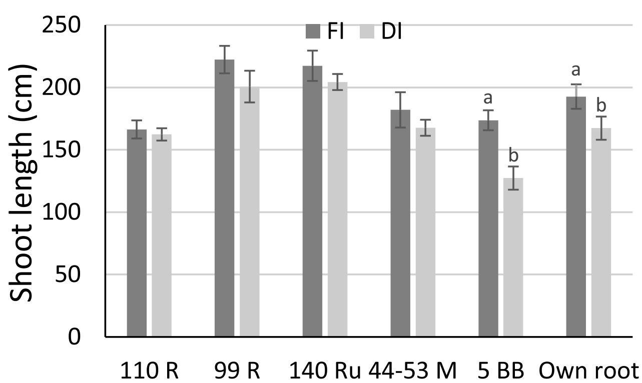

Fig. 2 Changes in shoot length of 'Michele Palieri' grapevines grafted on different rootstocks in response to different irrigation treatments. Each bar represents the mean ± standard error. Different letters within the same graft denotes significant differences ($p < 0.05$)

$H_2O\,m^{-2}\,s^{-1}$ (FI treated 140 Ru) to a maximum value of 498.8 mmol $H_2O\,m^{-2}\,s^{-1}$ (FI treated 44–53 M) in response to the rootstocks used. Afterwards, the gs values of all the vines sharply increased and reached the highest values on 01.08.2016. At this time, there were significant differences for the gs depending on the rootstocks. DI treatment drastically decreased the gs across the graft combinations, including the own-rooted vines. As illustrated in Fig. 1, the greatest change in gs was determined in own-rooted grapevines with a decrease of 38.5% and was followed by the vines grafted on 5 BB rootstock (36.6%). On the other hand, the lowest decreases were obtained from the vines on 110 R (15.5%) and 44–53 M (10.4%) rootstocks. Then, the gs consistently decreased during the rest of vegetation period. Among the gs values obtained on 21.08.2016, the only significant differences were found in grapevines grafted on 44–53 M and 5 BB. After this date, no significant difference occurred between the irrigation treatments.

Shoot length response of 'Michele Palieri' grapevines grafted on different rootstocks to different irrigation treatments is depicted Fig. 2. DI treatment decreased the shoot length of all the grapevines in varying degrees although the only significant changes were found in own rooted vines or those grafted on 5 BB rootstock (the hybrid of *Vitis berlandieri* × *V. riparia*). The greatest change resulting from DI was determined in 'Michele Palieri'/5 BB grapevines, decreasing from 173.7 to 127.3 cm (26.7% diminish). This was followed by own rooted vines with a 13.1% diminish from 192.7 to 167.3 cm. On the other hand, the lowest and statistically insignificant decreases were obtained from the vines grafted on 110 R (2.4%). Differences between the shoot lengths values of the vines grafted on the other rootstocks all of which are genetically originated form *Vitis berlandieri* × *V. rupestris* were statistically insignificant.

As can be seen in Fig. 3, DI treatment reduced the leaf area in varying degrees across the grapevines. The greatest decrease was found in vines grafted on 5 BB (24.4%) and was followed by own rooted vines (23.5%). On the other hand, the lowest and statistically insignificant decreases were obtained from the vines grafted on 140 Ru (9.2%) and 99 R (10.0%). Irrigation treatments did not sig-

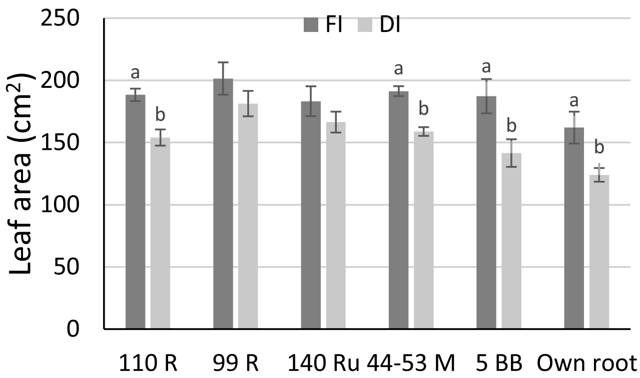

Fig. 3 Changes in leaf area of 'Michele Palieri' grapevines grafted on different rootstocks in response to different irrigation treatments. Each bar represents the mean ± standard error. Different letters within the same graft denotes significant differences ($p<0.05$)

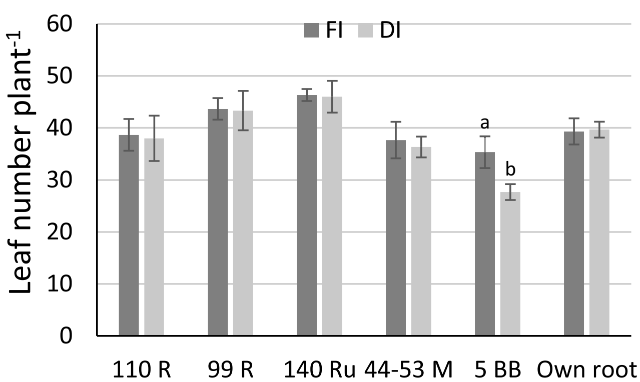

Fig. 4 Changes in leaf number of 'Michele Palieri' grapevines grafted on different rootstocks in response to different irrigation treatments. Each bar represents the mean ± standard error. Different letters within the same graft denotes significant differences ($p<0.05$)

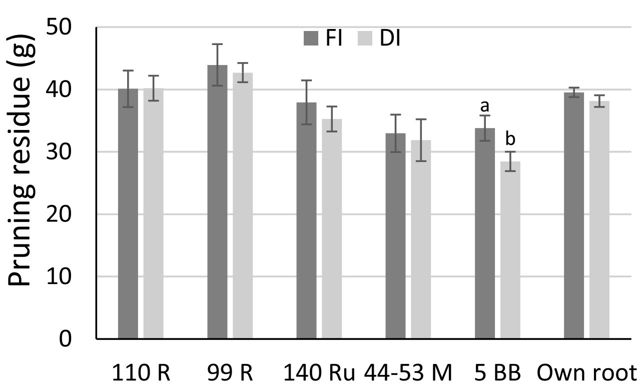

Fig. 5 Changes in pruning residue of 'Michele Palieri' grapevines grafted on different rootstocks in response to different irrigation treatments. Each bar represents the mean ± standard error. Different letters within the same graft denotes significant differences ($p<0.05$)

nificantly affect the number of leaves per plant, except for those grafted on 5 BB rootstock in which a significant decrease (21.6%) occurred (Fig. 4). Pruning residue (weight of winter pruning) values generally did not significantly change in response to DI among own rooted vines or grafted on 99 R, 110 R, 140 Ru and 44–53 M (Fig. 5). However, DI significantly decreased pruning residue weight when 5 BB was used.

Discussion

Grapevines are generally cultivated in regions with dry summers and, thus, they must endure several months of drought during its vegetation period (Lovisolo et al. 2010). The visible symptoms of drought stress during the vegetative development are leaf wilting, decreases in shoot length, leaf number and leaf area (Cramer et al. 2007). In the present study, although the vines of DI treatment showed visible symptoms of mild water stress (e. g., loss of turgor in shoot tips), no defoliation or leaf necrosis occurred. As known, water deficit can also cause disturbances in the water status of various organs (Medrano et al. 2003). Grapevines can resist drought stress by closing their stomata and reducing their leaf canopy (Flexas et al. 2002). In this study, DI treatment reduced the gs of 'Michele Palieri' scion cultivar in varying levels depending on the rootstock. Schultz (2003) reported that water stress influences gas exchange and water relations in grapevine cultivars in relation to difference in their hydraulic architecture. Grapevine rootstocks exhibit great variation about hydraulic properties (de Herralde et al. 2005), because they have different genetic backgrounds coming from various American species (Sabir et al. 2010).

Shoot growth is one of the most fundamental processes being remarkably influenced by water deficit stress. There are complex interactions between scion and rootstocks in terms of rootstock effects on scion growth. The rootstocks used in the study have differential effects on shoot growth of 'Michele Palieri' grapevines. High vigour rootstocks such as 110 R and 99 R induced shoot growth of the scion even under water deficit, while low vigour 5 BB limited the growth of the scion shoot. According to Wu and Cosgrove (2000), the degree of growth limitation can vary depending on the nature of the tissue, e. g. shoots, leaves or roots. In grapevine, high vigour rootstocks (such as *Vitis berlandieri* × *V. riparia* pedigree) have higher fineroot hydraulic conductivity due in part to higher aquaporin expression and activity (Gambetta et al. 2012). Nonetheless, the effect of vigour on the drought resistance of the plant is still not well-understood (Jones 2012). But, it has been postulated that using drought-tolerant rootstocks in the grapevine can help to minimize the effect of water deficit through improved water uptake and transport (Soar et al. 2006) and by controlling the transpiration via chemical signalling (Stoll et al. 2000) and hydraulic signaling (Vandeleur et al. 2009).

One of the first processes affected by water deficit is leaf growth. The leaf area of Michel Palieri grapevine was limited in varying degrees among the rootstocks in response to deficit irrigation regime. Similarly, Lebon et al. (2006) showed that developmental processes such as leaf number and leaf area were inhibited by water-deficit. They considered that these parameters are major determinant for adaptation to drought. Besides, Clingeleffer et al. (2011) reported several potential attributes, including pruning weight reduction for assessing drought tolerance. In fact, 5 BB was the only rootstock which decreased the weight of pruning residue as a result of water deficit condition, while other rootstocks similarly responded to water deficit. This finding support the general knowledge that the rootstocks belonging to *Vitis berlandieri* × *V. rupestris* may better perform than those of *Vitis berlandieri* × *V. riparia*.

Conclusion

The present study confirmed that the rootstocks markedly impaired the physiological and growth characteristics of the scion cultivar in varying degrees. This information is of practical value when deciding whether to use or not rootstocks for viticulturists, which will ultimately depend upon the environmental factors of viticulture area. Overall findings of this study imply that the rootstocks originating from *V. berlandiery* × *V. rupestris* hybrids (110 R, 99 R, 140 Ru and 44–53 M) better performed in a very similar genetic aptitude under deficit irrigation regime while the rootstock 5 BB (*V. berlandiery* × *V. rupestris*) showed more susceptible responses. On the other hand, the general response of own rooted vines were better than those grafted on 5 BB. Therefore, the use of one of *V. berlandiery* × *V. rupestris* hybrids may be better choice for viticulture under semiarid regions of the world.

Conflict of interest A. Sabir and Z. Sahin declare that they have no competing interests.

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