LONG-TERM IMPACT OF DEFICIT IRRIGATION ON THE PHYSIOLOGY AND GROWTH OF GRAPEVINE CV. 'PRIMA' GRAFTED ON VARIOUS ROOTSTOCKS

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ABSTRACT

Testing the globally popular grapevine rootstocks for affinity with new grape cultivars or tolerance potential to stress factors like drought is essential for districts where supplemental irrigation is more frequently needed due to the pressures of a global climate change. In this study, a seasonal evaluation of leaf gas exchange, leaf temperature, leaf greenness (chlorophyll content prediction) and vegetative development of *Vitis vinifera* L. cv. 'Prima' grafted to different rootstock genotypes having great variability in drought tolerance, were investigated. The experiment was conducted in a controlled experimental glasshouse on two-year-old soilless grown 'Prima' vines grafted on nine rootstocks [44-53 M, 5 BB, 140 Ru, Ramsey (Syn. Salt Creek), 99 R, Saint George (Syn. Rupestris du Lot), 41 B, 1613 C and 420 A]. A long-term deficit irrigation (DI) was imposed before bud break by reducing water supply to 40% of field capacity derived from concurrent measurements of water content of growth medium and maintained until the end of vegetation period. The rootstocks significantly modulated the physiology and vegetative growth of the scion cultivar in varying degrees according to their genetic features. Among them, 140 Ru rootstock found to be more prominent in terms of mitigating the adverse effect of water deficit on physiology and growth of the scion genotype 'Prima' as there were no significant difference between deficit and full irrigation treatments for most of parameters investigated. In general, the 'Prima' scion performed better when the rootstocks coming from *V. berlandieri* × *V. rupestris* pedigree rather than the others including *V. berlendieri* × *V. riparia*.

Key words: prima cultivar, grapevine rootstocks, water deficit, climate change

INTRODUCTION

On the face of ever-increasing global water shortage, together with temperature increase, the need to optimize available water resources in arid and semi-arid areas has urged the researchers to improve new water saving techniques, which have increased plant water use efficiency. In the context of improving the water productivity, there is a growing interest in deficit irrigation (DI) practice, an irrigation strategy whereby water supply is restricted and mild stress is allowed with minimal effects on plant physiology and yield. Under conditions of water scarcity, DI can lead to greater economic gains than maximizing the yields per unit of water supply for a given crop. Drought stress detection is a key factor in accurate irrigation scheduling tools [Steppe et al. 2008]. Several plant variables are used worldwide as plant water status indicators, such as leaf physiology [Chaves et al. 2010, Sabir 2016] and vegetative development [Myburgh

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2011]. But threshold values, beyond which plants start sensing the stress are dynamic, because plants are not only influenced by soil water availability, but also by microclimatic conditions [Zweifel et al. 2007, Steppe et al. 2008] and the rootstocks used [Marguerti et al. 2012]. The grapevine rootstocks display a great variability in response to abiotic stress factors [Koundouras et al. 2008], as they were bred from various American *Vitis* species [Sabir et al. 2010]. For viticulture in arid and semi-arid regions, drought-tolerant rootstocks would be desired as majority of vineyards around the world lack qualified or adequate irrigation water [Corso and Bonghi 2014]. Predictions on water scarcity in the near future increase the interest in drought tolerance afforded by rootstocks. Although mechanisms of tolerance to drought driven by rootstocks are not yet fully understood, rootstocks are expected to enable the scion to grow normally when water scarcity is experienced. In grapevine, vigorous rootstocks are believed to have higher fine root hydraulic conductivity in part due to higher aquaporin activity [Gambetta et al. 2012]. Under water deficit conditions, accordingly, the rootstocks with higher vigor rootstocks theoretically perform better than low vigor ones [Williams 2010]. However, the vigor is not a single factor that determines the drought tolerance of the vine. Previously, it has been postulated that using drought-tolerant rootstocks in the grapevine can help to mitigate the negative effect of water constraints *via* improved water uptake and transport [Soar et al. 2006] and by controlling the plant's transpiration through chemical signaling [Stoll et al. 2000] and hydraulic signaling [Vandeleur et al. 2009]. Furthermore, grapevine rootstocks have different rooting depth and densities [Smart et al. 2006], which in turns modulates the scion physiology and growth performance. On the other hand, it is not easy to understand the role of the rootstock on the adaptation of the scion cultivar to drought condition without considering the environmental factors and scion/rootstock interaction. In previous studies on young grafted grapevines, Tandonnet et al. [2010] reported that scion genotype can affect the root development of the rootstock. The anatomy of graft union, which differentiates the functions of phloem and xylem vessels, is also an important aspect in water transport. Padgett-Johnson et al. [2000] stated that rootstocks modify the leaf stomatal conductance

response of a scion cultivar to water deficit condition. Ezzahouani and Williams [2005], Williams [2010] and Koundouras et al. [2008] have each ranked the ability of commercial rootstocks to withstand drought (no irrigation) or deficit irrigation conditions. There were clear differences among the rootstocks regarding vine water relations and growth. However, it is uncertain if rankings of rootstocks for drought tolerance by the mentioned researchers would be applicable for new cultivars like 'Prima', and also for grape production in protected agriculture and soilless culture. Therefore, the aim of this study was to investigate the impacts of nine different worldwide common commercial rootstocks of various genetic background on the regulation of vine physiology of the scion cultivar 'Prima'.

MATERIALS AND METHODS

Experimental conditions. The experiment was conducted at the Research and Implementation Glasshouse of Selcuk University Agriculture Faculty in 2017. A good quality and very early maturing table grape cultivar 'Prima' was selected due to high convenience in glasshouse production. The vines (2-year-old at the beginning of the trial) were drip irrigated using one irrigation line per row, single emitter of 4 L h^{-1} per vine each. The study layout was a randomized complete block design with two irrigation regimes [Full Irrigation (FI) and Deficit Irrigation (DI)] and nine grafting combinations of the scion cv 'Prima' with various rootstocks commonly used worldwide. The rootstocks and their main characteristics were listed in Table 1.

For the study, two-year-old vines grown in about 70 L black plastic pots under controlled glasshouse condition were selected on the basis of homogeneity in vegetative growth. The vines were placed in east-west oriented rows with the spaces 0.5 × 1 m. The vines were grown in soilless culture using a growth medium consisted of sterile peat (Klassman®) and perlite mixture in equal volume. The pots were isolated from the ground with black plastic sheets. The vines were pruned to leave the single cane with 4 or 5 buds per vine. The summer shoots (4 or 5 shoots per vine) 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].

Table 1. Grapevine rootstocks and their response to abiotic stresses

Rootstock	Pedigree	Vigor*	Drought tolerance*
44-53 M	*V. riparia* Mich. × *V. rupestris* Scheele	M–H	H
5 BB	*V. berlandieri* Planch. × *V. riparia* Michx.	L–M	L
140 Ru	*V. riparia* Mich. × *V. rupestris* Scheele	H	H
Ramsey	*V. champinii*	H	M
99 R	*V. riparia* Mich. × *V. rupestris* Scheele	M–H	M–H
Saint George	*V. rupestris*	H	L–M
41 B	*V. vinifera* (cv. Chasselas) × *V. berlandieri*	M	M–H
1613 C	*Vitis soloris* × *V. labrusca* var. Othello	H	–
420 A	*V. berlandieri* Planch. × *V. riparia* Michx.	L	L

*Adapted from Galet [1979], Pongracz [1983], Carbonneau [1985], Wolpert et al. [1994], Lovisolo et al. [2016]. Vigor and tolerance level of rootstocks are reported as low (L), medium (M) and high (H)

All the vines received the same annual amount of fertilizer (approx. 10 g N, 8 g P, 7 g K) from May to August. Irrigation treatments were replicated three times in randomized blocks, with two vines per replicate.

Irrigations were performed according to the soil water matric potential (Ψm) levels using tensiometers (The Irrometer Company, Riverside, CA) placed at a depth of 20−22 cm and approximately 12 cm from the trunk, and were continuously applied from bud break (March) to the end of vegetation period (September). Water holding capacity level of growth medium was measured for adjustment of irrigation duration and amount. For this purpose, two randomly taken pots filled with known volume of oven-dried growth media were placed in large plastic buckets and kept for 6 h after watered with known quantity of water to attain the field capacity. Then the amount of the drained water in the bucket was measured and was subtracted from the total amount of water applied initially [Satisha et al. 2006]. The resulting value was considered the volume of the irrigation water that has to be applied to attain 100% field capacity (FI) for beginning of the study. Forty 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 slightly modified procedure described by Myburgh and van der Walt [2005]. Ψm were continuously recorded with daily readings at around 13.00 pm as well as before and after irrigations [Okamoto et al. 2004]. For DI, irrigation was started when Ψm reached 38−40 kPa and was terminated when the calculated amount of water was applied [Sabir 2016]. Monitoring of the data following irrigation was continued throughout the experiment season, and the irrigation duration was adjusted if necessary. Relatively higher air temperature in the glasshouse was kept to simulate typical semi-arid Mediterranean climate. In the hot and dry days, excessive heat accumulation in glasshouse was avoided by opening the roof and sidewall windows. The instantaneous daylight intensity inside the glasshouse was between 61200 and 78500 lux (Lutron LX-105) at around 13.00 pm.

Plant measurements. Physiological responses of mature leaves were investigated with the measurements of stomatal conductance (g_s), temperature (T_{leaf}) and chlorophyll concentration estimation at four different times during the vegetation period. The g_s and temperature (T_{leaf}) measurements were performed using the 5th or 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 sun-exposed leaves at the outer canopy were used for measurements [Johnson et al. 2009, Greer and Weedon 2013]. The g_s was measured near the central vein of the leaf blade [Düring and Loveys 1996, Stavrinides et al. 2010] with a steady state porometer (SC-1 Leaf Porometer) [Zufferey et al. 2011] and was expressed as mmol H_2O m^{-2} s^{-1}. For all leaves, the same area was chosen to put porometer censor [Miranda et al. 2013], because instantaneous g_s may

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].

Growth responses of the vines to irrigation treatments were determined with investigations on leaf and shoot development. Leaf fresh weight, leaf dry weight and leaf area were investigated on fully expanded healthy mature leaves of representative grapevines of each treatment [Tramontini et al. 2013a]. Fifteen leaves per treatment were immediately weighed to determine the fresh weight. To determine single leaf area, one fully-expanded mature leaf from the mid-shoot area of each plant was used in order to minimize age effects. After fresh weight records, the leaves were placed in an oven at 70°C for 48 h in order to obtain the dry mass. All mass measurements were made using an analytical scale with precision of 0.0001 g. Leaf area was estimated using WinFolia computer software program. Shoot length (all the scion shoots were measured with a sensitivity of 1 mm), and shoot diameter (measured by digital compass at a point 1 cm above the second node) were measured at the end of growth period around the cessation of shoot elongation [Sabir 2013].

Instantaneous air temperature and air humidity (using mobile data logger EBRO EBI 20) inside the experimental glasshouse were recorded to track growth condition of experimental grapevines [Hirayama et al. 2006]. The recordings were read with the software Winlog-Basic.

Statistical analyses. A complete randomized block design with three replicates (consisted of two grafted vines each) was established. As expected, the canopy size of the scion cultivar 'Prima' was apparently heterozygous due to wide variations in rootstocks vigor, therefore, data were separately evaluated for each rootstock by analysis of variance (ANOVA). 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).

RESULTS

Irrometer (soil tensiometer) readings (separately recorded for FI and DI), air temperature and air relative water content values of experimental season

have been illustrated in Figure 1. During vegetation period, daily air temperature and relative humidity, recorded using data logger (Ebro EBI 20 TH1) inside the glasshouse, were 28.7−40.3°C and 21.4−40.3%, respectively. The optimum temperature for grapevines is generally between 25 and 35°C (77 and 95°F). During the early development stages, when the shoot elongates fast, grapevines are subjected to important chemical transformations and, as a consequence, they are sensitive to extremely hot temperatures. During the study, tensiometer readings at midday (13.00 pm) were around 0.7−12 kPa (centibars) and 30−38 kPa for FI and DI conditions, respectively.

Leaf fresh weight of 'Prima' grapevine was significantly decreased by DI treatment for all the grafting combination, except for 140 Ru (Fig. 2). The greatest decrease, from 2.52 g to 1.8 g, occurred in 'Prima'/420 A vines (28.7%), which was followed by 'Prima'/Saint George (26.8) and 'Prima'/4453 M (25.6%). On the other hand, the lowest decrease was investigated in 'Prima'/140 Ru grafts (2.2%) and it was followed by 'Prima'/41 B (8.7%). In five grafting combinations among the total of nine, more than 15% diminish in leaf fresh weight due to DI was found. Leaf dry weight values of all the grapevines subjected to DI were lower than those of FI vines, although the differences were insignificant in three of the graft combinations with rootstocks 140 Ru, 99 R, 41 B and 1613 C (Fig. 3). Similar to fresh weight observations, the greatest decrease due to DI was obtained from 'Prima'/420 A graft combination (21.9%). As it was seen in leaf fresh weight, expectedly, the lowest decrease in response to DI was obtained from 'Prima'/140 Ru vines (1.6%), which was followed by 'Prima'/41 B (2.1%).

Findings on single mature leaf area are quite similar to those of leaf fresh weight in that DI treatment resulted in significant decreases in area of the leaves, except for those grafted on 140 Ru and 41 B (Fig. 4). The greatest decrease occurred in 'Prima'/420 A vines (28.0%), which was followed by 'Prima'/Saint George (26.2%) and 'Prima'/5 BB (20.4%). The leaves of six graft combinations with the rootstocks 44-53 M, 5 BB, Ramsey, 99 R, Saint George, 1613 C and 420 A underwent a marked decrease more than 16%, indicating the great adverse effect of DI on leaf area.

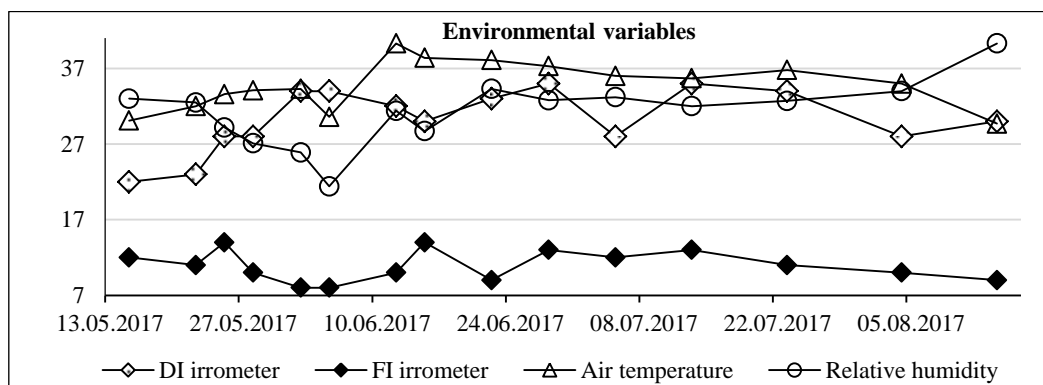The shoot lengths of most grafting combinations were significantly decreased by DI treatment, except for

Fig. 1. Seasonal variation in irrometer readings of FI and DI, including air temperature and air relative humidity
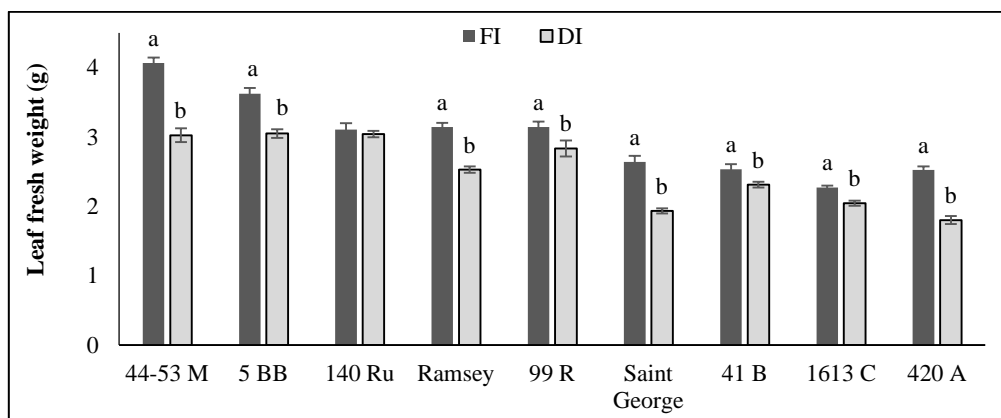

Fig. 2. Leaf fresh weight (g) response of 'Prima' scion to irrigation treatments (FI: full irrigation, DI: deficit irrigation) and rootstock. Values of bars indicated by different letters identify significantly different groups (P < 0.05, LSD test). Bars represent standard errors
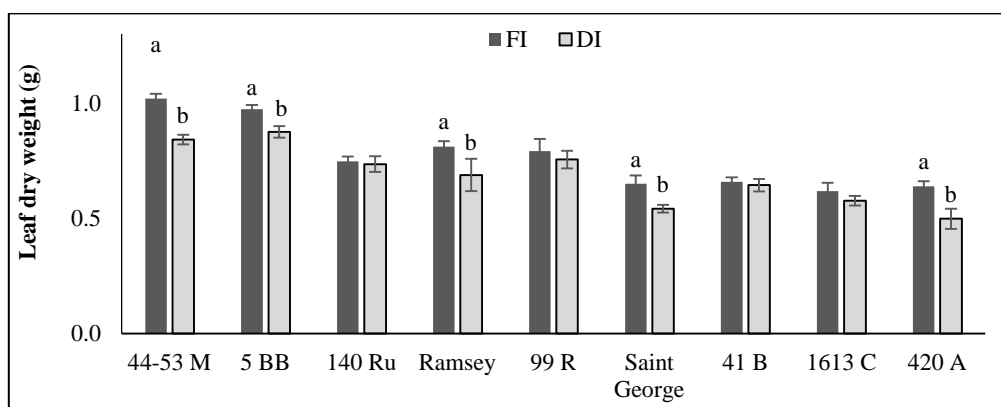

Fig. 3. Leaf dry weight (g) response of 'Prima' scion to irrigation treatments (FI: full irrigation, DI: deficit irrigation) and rootstock. Values of bars indicated by different letters identify significantly different groups (P < 0.05, LSD test). Bars represent standard errors
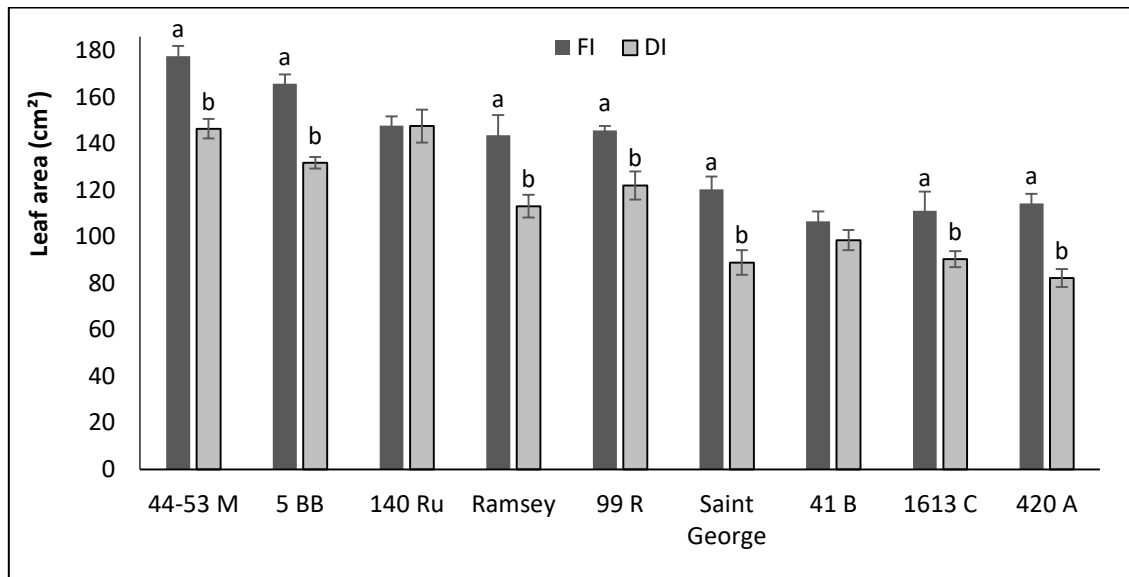
Fig. 4. Leaf area (cm^2) response of 'Prima' scion to irrigation treatments (FI: full irrigation, DI: deficit irrigation) and rootstock. Values of bars indicated by different letters identify significantly different groups (P < 0.05, LSD test). Bars represent standard errors
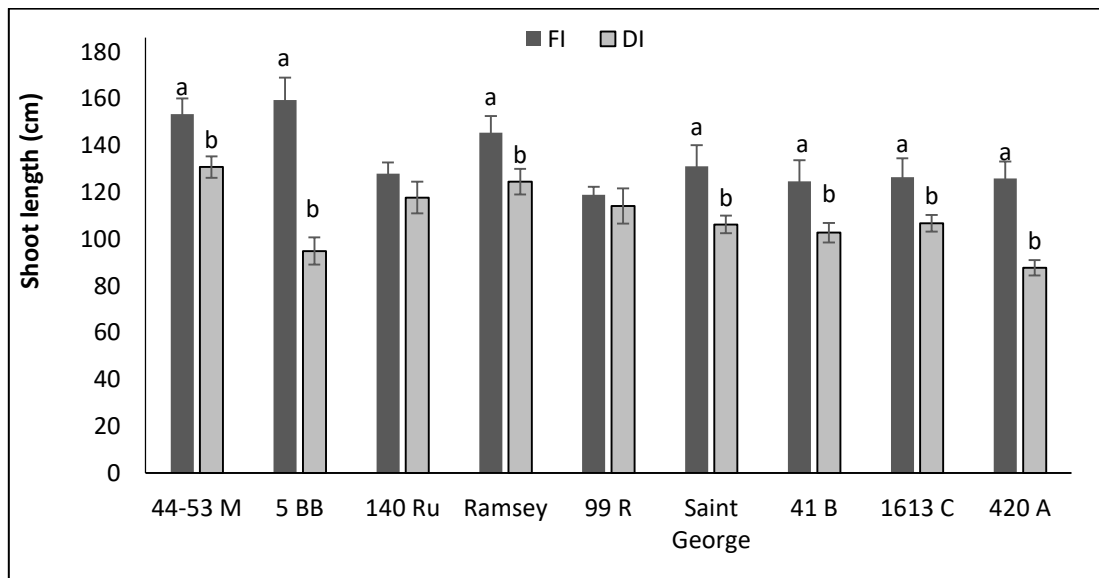

Fig. 5. Shoot length (cm) response of 'Prima' scion to irrigation treatments (FI: full irrigation, DI: deficit irrigation) and rootstock. Values of bars indicated by different letters identify significantly different groups (P < 0.05, LSD test). Bars represent standard errors
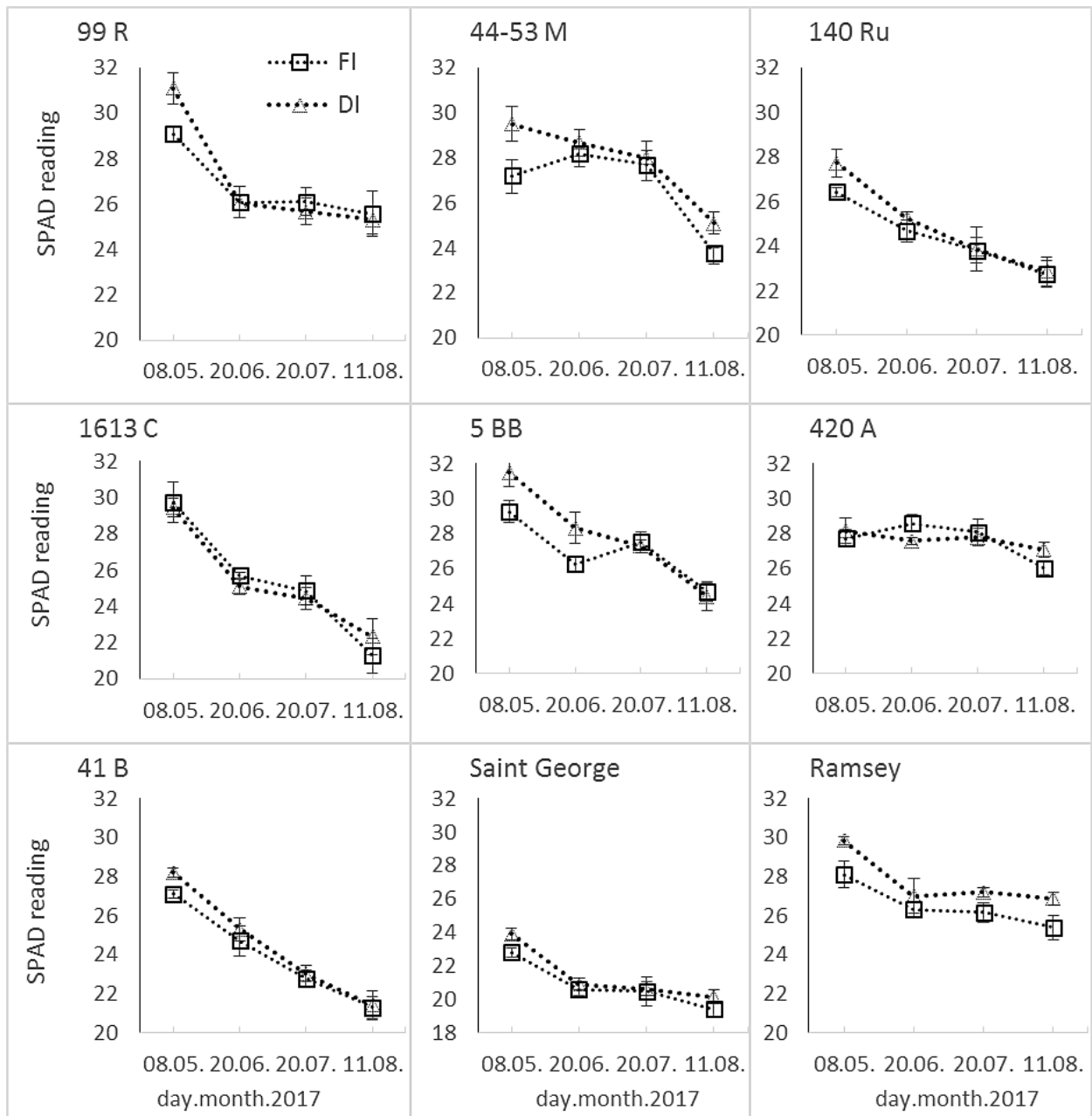
Fig. 6. Seasonal evaluation of leaf SPAD value for all grafting combinations. Each point represents the average of six measurements with SE. Bars not visible indicate SE smaller than symbol. DI, deficit irrigation; NI, non-irrigated; FI, full irrigated; PRD, partial root drying

Fig. 7. Seasonal evaluation of leaf stomatal conductance (mmol $m^{-2}sn^{-1}$) for all grafting combinations. Each point represents the average of six measurements with SE. Bars not visible indicate SE smaller than symbol. DI, deficit irrigation; NI, non-irrigated; FI, full irrigated; PRD, partial root drying
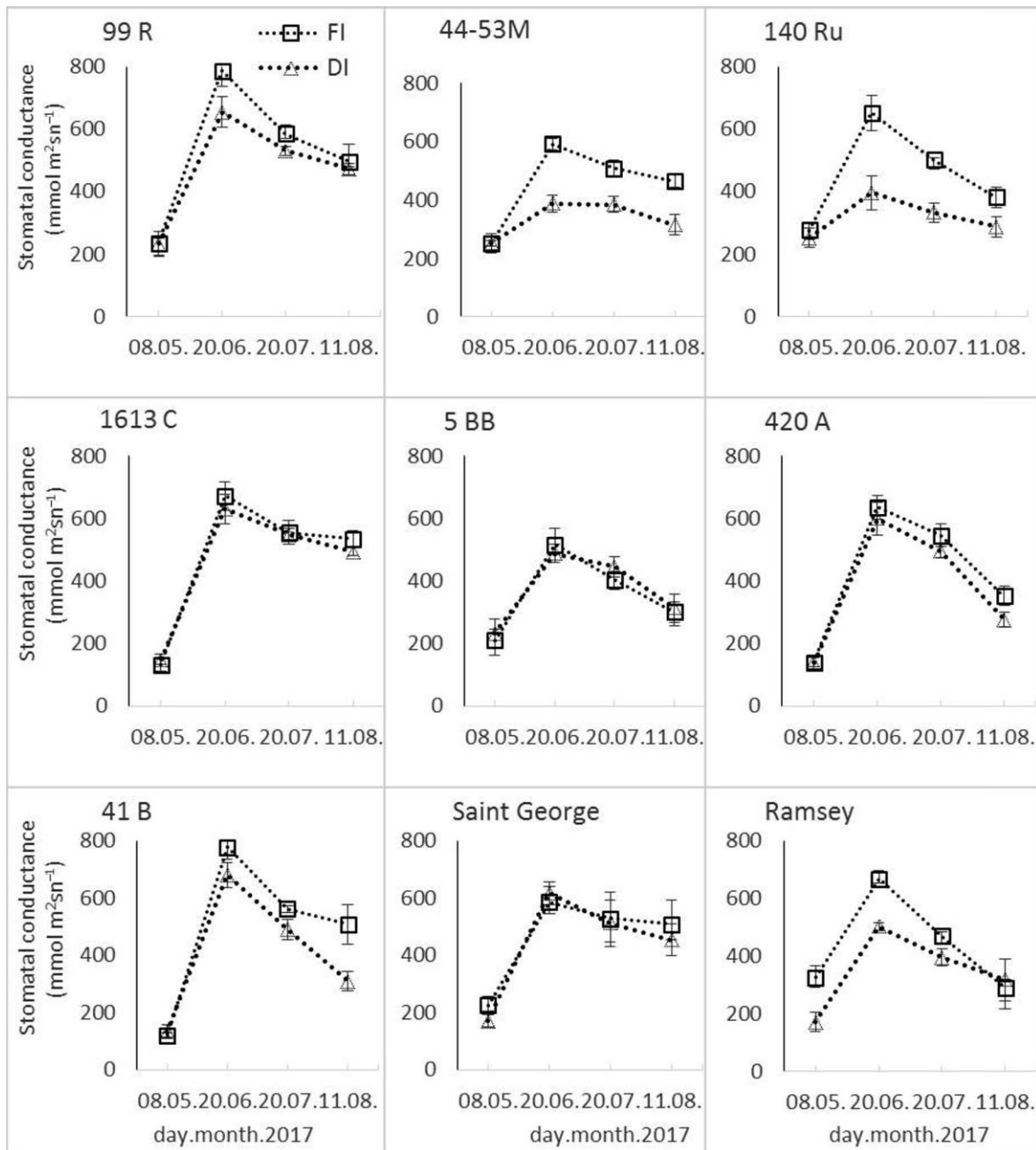
Fig. 8. Seasonal evaluation of leaf temperature (°C) for all grafting combinations. Each point represents the average of six measurements with SE. Bars not visible indicate SE smaller than symbol. DI, deficit irrigation; NI, non-irrigated; FI, full irrigated; PRD, partial root drying
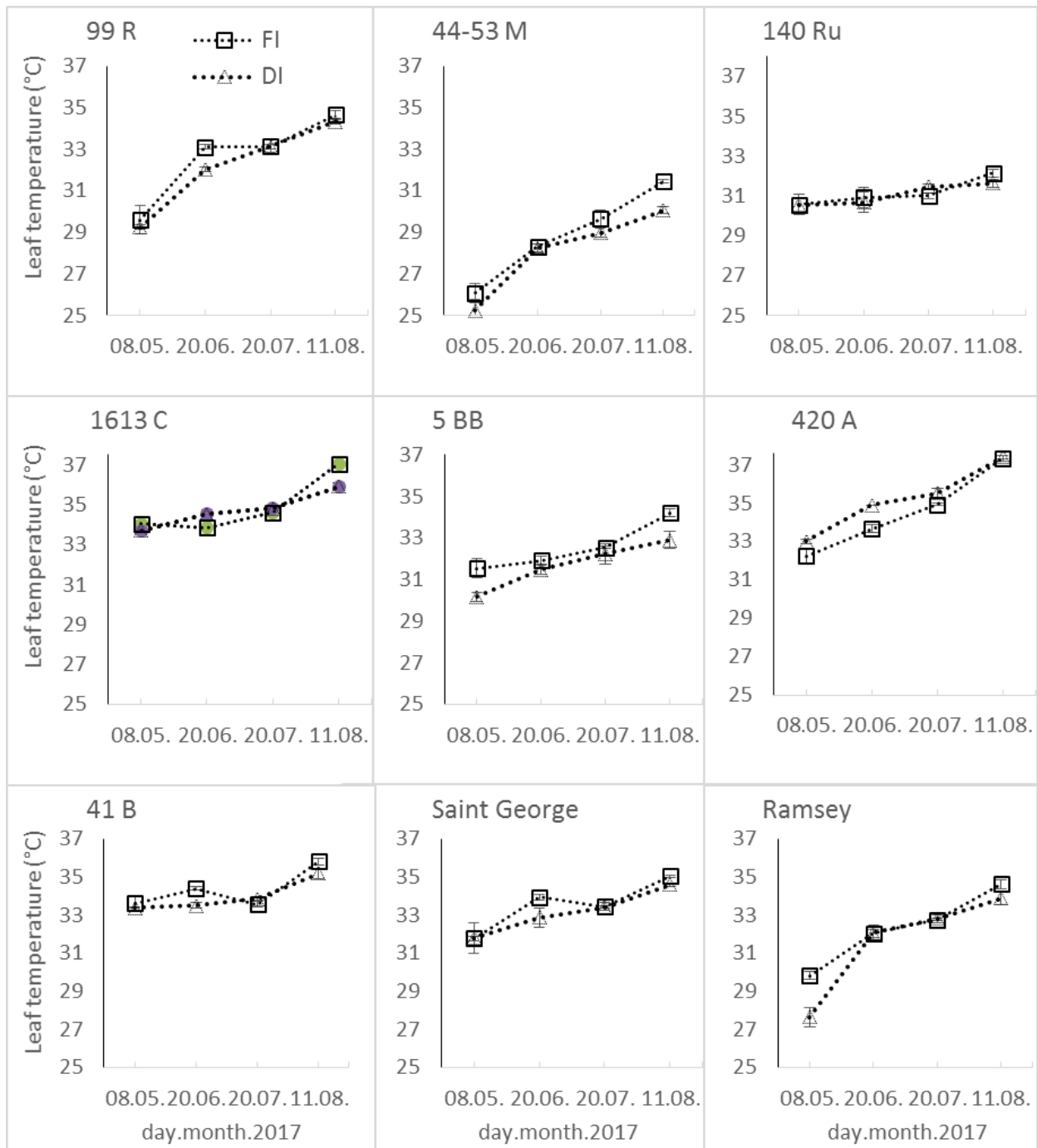
those grafted on 140 Ru and 99 R (Fig. 5). The greatest and very strong decrease, from 159.3 cm to 94.8 cm, occurred in 'Prima'/5 BB vines (40.4%), which was followed by 'Prima'/420 A (30.3). On the other hand, the lowest and insignificant decreases were found in 'Prima'/140 Ru grafts (7.9%) and 'Prima'/99 R (4.0%). Similar to leaf fresh weight findings, in five grafting combinations among the total of nine, more than 15% diminish in shoot length due to DI was found.

Seasonal changes in leaf chlorophyll content estimated by SPAD readings in mature leaves of 'Prima' grapevines grafted on different rootstocks are depicted in Figure 6. According to the first observations (08.05.2017), SPAD reading values of all the grapevines, except for those grated on 420 A rootstock, were at the highest level in early growth season, when the shoot elongation was also at maximum level. At this growth stage, there were significant differences in SPAD values of 'Prima' grated on all the rootstocks in response to DI treatment, except for 420 A. SPAD values of DI plants were generally higher than those of FI with the exception of 1613 C graft, the values of which were almost the same for both treatments. Afterwards, SPAD values of the grapevines displayed a general decreases during the summer period. SPAD values on 20th June and 20th July revealed almost no significant differences between the irrigation treatments across the rootstock used, except for two occasional changes in 5BB and Ramsey. In the late summer, when the shoot growth was approaching to cessation, certain significant changes in SPAD values in grafts of 44-53 M, 420 A and Ramsey were apparent.

Seasonal time courses of stomatal conductance (g_s), also known as leaf gas exchange, were recorded in 'Prima' grapevines grafted on different rootstocks. As illustrated in Figure 7, the g_s at early season (8th May) was very low and similar for irrigation treatments, except for the vines grated on Ramsey. Later, the g_s across the graft combination has raised dramatically reaching the maximum values changing with respect to rootstocks and treatments on 20th June. At this growth stage, there were significant decreases in the g_s values resulting from DI, the treatment for grafts using 140 Ru, 44-53 M, Ramsey and 99 R with the decreases of 39.2%, 34.4%, 24.8% and 16.7%, respectively, while the others did not significantly respond to DI treatments. During the summer period, significant

decreases due to DI in g_s of 'Prima' scion were determined when 44-53 M and 140 Ru rootstocks were used. The g_s values of graft combinations with 1613 C, 5 BB and Saint George were persistently similar between the treatments during the season.

The leaf temperature (T_{leaf}), varying according to the rootstocks used, gradually increased during the vegetation period (Fig. 8). According to the findings recorded on 08th May, the T_{leaf} values of DI-subjected vines with the rootstocks 5 BB, 420 A and Ramsey were significantly lower than those of FI vines, whereas there were no significant differences between water levels for the remaining grafts. On 20th June, the T_{leaf} values of FI treatment grafts of 99 R, 41 B and Saint George were significantly higher than their DI vines. Conversely, general T_{leaf} values of DI grapevines belonging to 'Prima'/420 A grafts were higher than that of FI up to 11.08.2017. On the other hand, T_{leaf} values of 'Prima'/140 Ru grafts were almost the same for both treatments. The overall investigations on T_{leaf} indicated that the leaf temperature response of the 'Prima' grapevine is primarily related with the rootstock used rather than irrigation treatments, although T_{leaf} values in FI treatment were mostly higher than those of DI treatment. It is noteworthy that 140 Ru, among the rootstocks, enabled the temperature of the scion leaf to maintain more stable during the growth season, non-responsive to water deficit.

DISCUSSION

Global water shortage, together with high temperatures, is predicted as the most severe environmental problem for the 21st century and drought is a major abiotic factor that reduces agricultural productivity [Yuan et al. 2010]. Drought induces the senescence of mature leaves [Jackson 1997], decreasing plant water potential, transpiration and photosynthetic rates [Yordanov et al. 2000]. Changes in leaf characteristics have been known as good and reliable indicators for understanding the tolerance aptitude of plants [Davies et al. 2000]. In the present study, significant variations in leaf growth parameters, such as fresh weight, dry weight and area of single leaf, have been determined in relation to water treatments and rootstock usage. The degree of leaf growth limitation can vary depending on the nature of the tissue [Wu and Cosgrove

2000] that is affected by many factors, including the rootstocks used [Tramontini et al. 2013b, Sucu et al. 2017]. Therefore, the sensitivity of growth to drought will depend on regulation at the growth and physiological levels. In terms of drought tolerance, grapevine rootstocks are expected to enable the scion to function and grow normally when water is limited. In this relation, 140 Ru enabled the leaf growth of 'Prima' scion cultivar as there were no significant differences between the leaf growth parameters of non-stressed and stressed plants. Higher drought tolerance manner of 140 Ru could be related with capacity to develop higher root surface as stated previously by Tramontini et al. [2013b]. Shoot growth is also proven as one of the most sensitive plant processes to water stress [Dry et al. 2000] and may stop with a slight reduction in leaf tissue water [Hsiao and Xu 2000]. The rootstock genotypes had significantly different effects on the shoot growth of the scion cultivar under the stress of water deficit. Similarly to the leaf features, 140 Ru maintained a well-balanced shoot growth, even under water deficit stress with no significant difference between FI and DI. Previously, Carbonneau [1985] and Southey [1992] ranked 140 Ru as resistant to drought. Besides, 99 R displayed similar results about shoot growth of the scion, indicating better tolerance together with 140 Ru, both of which originate a cross between *Berlandieri × Rupestris*. Indeed, the genotypes coming from this crossing are reported to possess higher tolerance aptitude than those of *Berlandieri × Riparia* crosses [Koundouras et al. 2008], an important rootstock group used worldwide. Apparently higher sensitivity of scion grafted on *Berlandieri × Riparia* rootstocks 5 BB and 420 A compared with *Berlandieri × Rupestris* (140 Ru and 99 R) proves the mentioned study. Embolisms, as hydraulic signals, induce the closure of stomata in order to limit water use by the plant and protect against the propagation of low xylem tension to the stem. Susceptibility to embolism in rootstocks was shown to be associated to root system architecture and aquaporin contribution to water flow during water stress [Perrone et al 2012]. The rootstock genotype can modulate the intrinsic response of scion cultivar to water stress through both ABA and hydraulic signaling [Lovisolo et al. 2002, Lovisolo et al. 2008, Lovisolo et al. 2010]. This hypothesis is proven by experimenta findings where drought-resistant (140Ru,

V. berlandieri × V. rupestris) and drought-sensitive rootstocks (SO4, *V. berlandieri × V. riparia*) can respectively shift the threshold of stomatal closure towards lower (140Ru) or upper (SO4) Ψ_{leaf} in either a near-iso- (*V. vinifera* cv. Grenache) or near-anisohydric cultivars (*V. vinifera* cv. Syrah) in a water-stress situation [Tramontini et al. 2013b]. In a recent study, Pagliarani et al. [2017] reported that the accumulation of related miRNAs differentially modulated by drought stress grafted grapevines. The drought responses of a plant involve a series of physiological changes. The g_s is known as an important physiological process for the response to drought in grapevines [Koundouras et al. 2008] as it directly influences the vine water status. Furthermore, a study carried out on QTLs identified one genomic region of the grapevine rootstock that was related to water extraction capacity and scion transpiration [Marguerti et al. 2012]. Analyzing the factors influencing the stomatal conductance of grapevines, Lavoie-Lamoureux [2017] revealed that stomatal sensitivity to water stress in *V. vinifera* genotypes is further enriched by the diversity of scion/rootstock combinations. The mentioned findings support the general results of the present study that rootstocks differ in their ability to provide water to the scion and that g_s. Simultaneous measurements of T_{leaf} and g_s in this study revealed that some rootstocks led the scion higher capacity of dissipation *via* evaporative cooling due to larger g_s 99 R and 1613 C. Supposedly, such relatively larger seasonal g_s course may be a response to high T_{leaf} course measured in vines grafted on the same rootstocks 99 R and 1613 C. Considering the sudden air temperature increase after 10th June (Fig. 1) along with accompanying increase in g_s of general vines on around 20th June (Fig. 6), it is quite evident that the stomatal responses to high temperatures probably accounted for the increased transpiration. In spite of this physiological relation, general results of previous and current studies the g_s or T_{leaf} itself cannot determine the drought tolerance level of a given genotype, because these parameters are very sensitive to instantaneous climatic factors as previously described by Sabir and Yazar [2015].

CONCLUSION

The present study aimed to obtain an experimental knowledge of the effects of various grapevine

rootstocks on physiology and growth performance of 'Prima', a very early ripening good quality table grape cultivar. Climate change-related phenomena (water deficit together with increasing temperature) were simulated under controlled glasshouse condition with soilless culture. Overall, the leaf and shoot growth of the scion cultivar were not markedly affected by DI treatment, when 140 Ru was used as a rootstock. 140 Ru led the scion leaf temperature and greenness maintain more stable during the growth season, non-responsive to water deficit. It also seemed to help the scion better regulate the g_s in response to water shortage. Consequently, of nine rootstocks coming from various genetic origins, 140 Ru performed better in mitigating the reverse effects of water deficit and high temperature on growth and physiology of the scion 'Prima'. Thus, it has given promising results in combating with ever-increasing global water shortage and temperature extremes.

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