Journal of Agricultural and Crop Research
Vol. 6(6), pp. 105-109, December 2018
doi: 10.33495/jacr_v6i6.18.147
ISSN: 2384-731X
Research Paper

Leaf physiology and fruitfulness of grapevines (*V. vinifera* L.) as affected by rootstock use and sustained water deficit

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Accepted 18th December, 2018.

Abstract. Global climate change has forced researchers to improve sustainable strategies to efficiently use limited water sources. In this scope, the use of tolerant rootstocks and deficit irrigation are two essential issues. The present experiment was conducted to examine the effects of water stress on grafted or non-grafted grapevines of Alphonse Lavallée and Crimson Seedless and to compare the responses of two grapevine cultivars to contrasting irrigation methods. Genotypes responded differently to rootstock use and water deficit. Rootstock use markedly increased the stomatal conductance (g_s) for both cultivars. Deficit irrigation treatment resulted in significant decreases in g_s of overall vines, except for those own rooted Alphonse Lavallée cultivar. In both grafted and own rooted vines of Crimson Seedless, leaf temperature (T_{leaf}) was significantly higher in FI vines than those of DI. Findings demonstrated that there is a direct positive response of g_s to increasing T_{leaf} in two grapevine cultivars. But such response was cultivar-depended with a stronger response of Crimson Seedless cultivar.

Keywords: Water deficit, plant stress, deficit irrigation, grapevine physiology, fruitfulness.

INTRODUCTION

Sustainable methods to increase crop water productivity are gaining importance in arid and semiarid regions as the portion of fresh water currently available for agriculture is gradually decreasing. Recent focus has shifted to the limiting factors in production systems, notably the availability of either agricultural water or land. Deficit irrigation (DI) has been widely investigated as a valuable regime for dry regions (Fereres and Soriano, 2007) where water is the limiting factor in agriculture. DI is an irrigation method whereby water supply is limited and mild stress is allowed with minimal influences on plant physiology. The purpose is that any yield reduction will be insignificant compared with the benefits gained through conserved water. DI techniques have been widely used in wine grapes (Okamoto *et al*., 2004; Kounduras *et al*., 2008; Sabir, 2016a), although there are limited available data on table grapes, except for a few studies recently published (Sabir *et al*., 2017). Sabir *et al*. (2017) revealed that deficit irrigation (watering at 50% of field capacity) may be a potential irrigation method for grapevines when accurately optimized according to specific requirements of different grapevine genotypes. On the face of ever-increasing global climate change, drought-tolerant rootstocks would be recommended for a sustainable viticulture in arid and semi-arid regions where majority of vineyards around the world lack quality or adequate irrigation water (Corso and Bonghi, 2014). Originating from various American *Vitis* species, the rootstocks differently response to drought stress since they exhibit a great genotypic variation as previously DNA fingerprinted by Sabir *et al*. (2010). Many factors affect the tolerance level of grapevines to drought stress.

Scion/rootstock affinity and interaction is also essential for a sustainable viticulture under drought condition. The current experiment was therefore undertaken, (1) to examine the effects of water stress on grafted or non-grafted grapevines, and (2) to compare the responses of two grapevine cultivars to contrasting irrigation levels.

MATERIALS AND METHODS

Plant material and cultivation

Two years old grapevine (*Vitis vinifera* L. cv. Alphonse Lavallée and Crimson Seedless) plants either grafted on drought tolerant rootstock 99 R (*V. berlandieri* × *V. berlandieri*) or own-rooted (nongrafted) were cultivated in approximately 15 L pots under controlled glasshouse condition of Selcuk University (Konya, Turkey). At the beginning of the experiment, healthy vines were selected on the basis of homogeneity in vegetative growth. Growth medium consisted of equal mixture of peat and perlite. Treatments were replicated three times with four vines per replicate. Prior to bud break, the Alphonse Lavallée vines were spur pruned to leave 4-5 winter buds per plant (two spur canes with two buds on each) while Crimson Seedless had 6-7 buds on two canes after pruning. Night and day temperatures inside the glasshouse were 18 ± 5 and 33 ± 6°C, respectively (Data logger, Ebro EBI 20 TH1). The plants were watered every two day with equal amount of fresh tap water (0.7 to 1.2 L per plant according to weather conditions). The summer shoots were tied with thread to the wires 2.2 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 from April to August.

Study layout

Experimental design was a randomized complete block design with two irrigation regimes [full irrigation (FI) and deficit irrigation (DI)] and two root systems (own root or grafting on 99 R) for each cultivar. Grapevine cultivars were allotted to main plots while irrigation levels to subplots. Each irrigation method consisted of three replications with 4 grapevines per replicate. Irrigations were scheduled according to soil water matrix potential (Ψm) levels using several tensiometers (The Irrometer Company, Riverside, CA) as described by Satisha *et al*. (2006) with minor modifications. Mild stress conditions has been tried to establish with DI (approx. 50% of FI).

Measurements

Stomatal conductance (g_s) and temperature (T_{leaf}) mature leaves were recorded 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). Healthy and mature but not senescent sun-exposed leaves at the outer canopy were used for measurements (Johnson *et al*., 2009). The g_s was measured near the central vein of the leaf blade (Düring and Loveys, 1996) 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. T_{leaf} was also simultaneously recorded at each measurement. Bud break rate and fruitfulness was assessed in the following season. Fruitfulness was determined when shoot length was ~40 cm and was expressed as number of inflorescences per node.

Statistical analysis

The collected numerical data were subjected to statistical analysis. Each treatment was designed with three replicates consisting of four plants. The mean values of cultivars were compared separately, as the genotypes differ in their genotypic characteristics. Irrigation treatments were also considered separately. Statistical tests were performed at $P < 0.05$ using SPSS 13.0 for Windows (SPSS Inc., Chicago, IL, USA), using the least significant difference (LSD) test.

RESULTS AND DISCUSSION

Changes in leaf temperature (T_{leaf}) were illustrated in Figure 1. In own rooted vines of Alphonse Lavallée cultivar, T_{leaf} was significantly higher in FI vines than those DI, while there was no significant difference among the treatment in grafted vines. In both grafted and own rooted vines of Crimson Seedless, T_{leaf} was significantly higher in FI vines than those of DI. Rootstock use markedly increased the T_{leaf} for both cultivars. In a previous study Sabir *et al*. (2017) also reported that rootstocks had variable effects on leaf temperature of soilless grown Michele Palieri table grape cultivar. Temperature is a major factor for regulation of gas exchange through the leaf in grapevines as has been demonstrated by Palliotti and Cartechini (2005). Thus, photosynthesis activity is strongly related with the leaf temperature.

In grafted Alphonse Lavallée grapevines, the g_s was significantly higher in FI vines grafted on 99 R than those of DI vines, while the g_s of own rooted vines was not significantly affected by irrigation treatment (Figure 2). In both grafted and own rooted vines of Crimson Seedless, the g_s was significantly higher in FI vines than those of DI. Quite similar to the findings on T_{leaf} rootstock use markedly increased the g_s for both cultivars. DI irrigation treatment resulted in significant decreases in g_s of overall

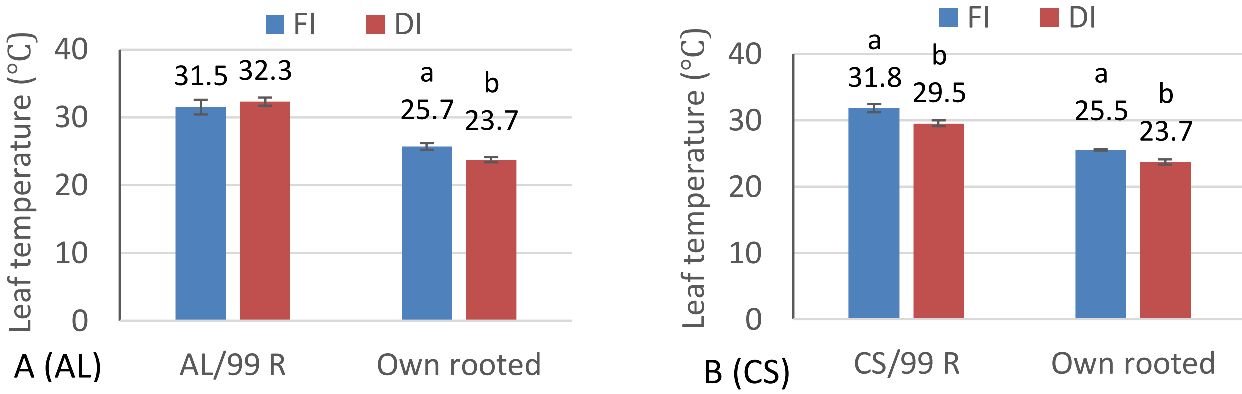

Figure 1. Leaf temperature of Alphonse Lavallée (A) and Crimson Seedless (B) cultivars as affected by rootstock use and sustained water deficit. (FI: full irrigation, DI: deficit irrigation). Vertical bars indicated by different letters identify significantly different means (P < 0.05, LSD).

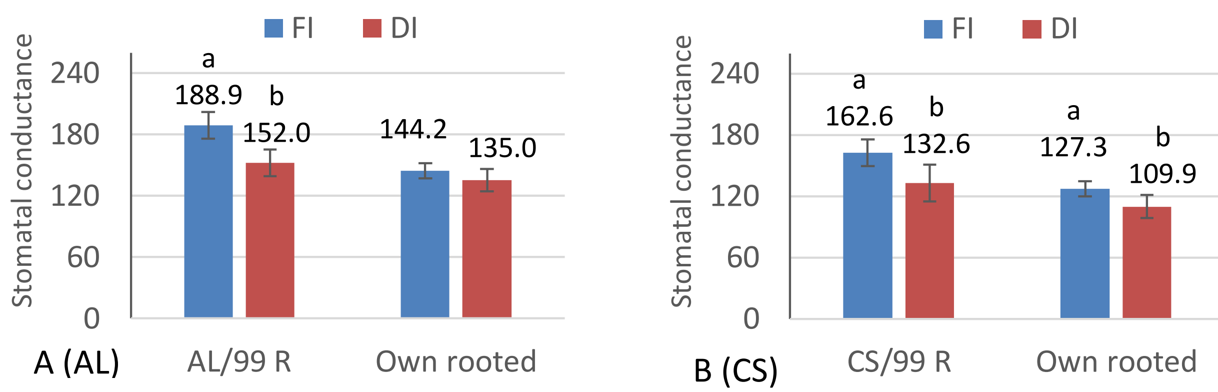

Figure 2. Stomatal conductance of Alphonse Lavallée (A) and Crimson Seedless (B) cultivars as affected by rootstock use and sustained water deficit. (FI: full irrigation, DI: deficit irrigation). Vertical bars indicated by different letters identify significantly different means (P < 0.05, LSD).

vines, except for those own rooted Alphonse Lavallée cultivar. These findings are in well agreement with those of Padgett-Johnson *et al*. (2000) who stated that rootstocks modify the leaf stomatal conductance response of scion cultivar to water deficit condition. Therefore, proper rootstock selection has an essential role to mitigate adverse effects of the increasing drought stress on grapevine physiology in arid and semiarid regions of the world.

The effects of irrigation level and rootstock on bud break rate of the cultivars have been illustrated in Figure 3A and B. In both cultivars, iirigation level did not significantly affect the bud break rate when 99 R rootstock was used althouh slight decreases were detected. However, own rooted vines of both cultivars significantly affected by DI. There were 11.4 and 14.4% reductions in bud break rate due to DI in own rooted vines of Alphonse Lavallée and Crimson Seedless cultivars, respectively. The effect of water deficit on bud break rate of the grafted vines was more apparent in Crimson Seedless than Alphonse Lavallée, indicating the differential effect of scion genotype on plant physiology. Early bud break is appreciated in subtropical regions for early ripening, while in temperate climates it may result in freeze damage due to unexpected cold weather condition in the spring.

Availability of water around the roots could be related to temperature and light conditions in a particular season and such climatic parameters might influence the bud fruitfulness of grapevines. As illustrated in Figure 4A and B, bud fruitfulness levels of the cultivars significantly affected by irrigation method regardless of the rootstock use. In Alphonse Lavallée, there were 15.7 and 12.3% reductions due to DI in bud fruitfulness for grafted and nongrafted vines, respectively. There were similar results in Crimson Seedless cultivar where DI method reduced the bud fruitfulness of grafted and nongrafted vines by 14.6 and 15.0%, respectively. Such decrease in fruitfulness due to water deficit may be interpretted as acceptable when widespread drought conditions around

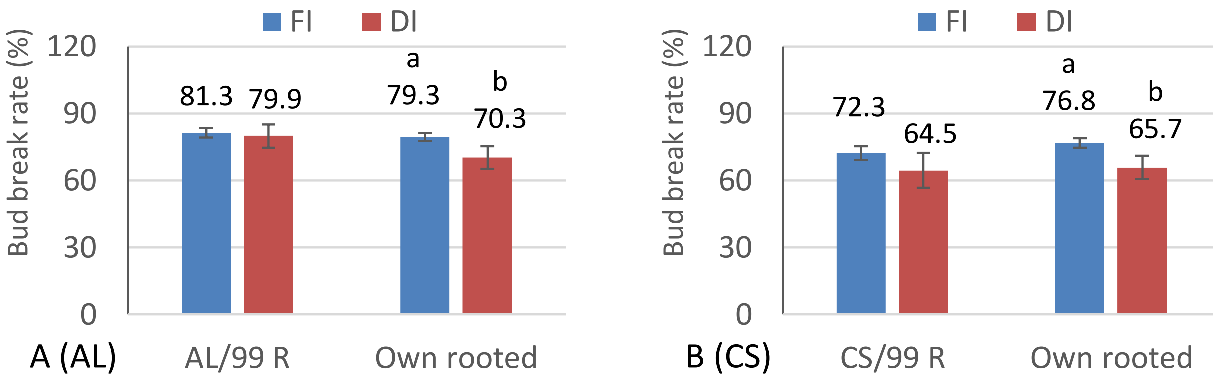

Figure 3. Bud break rate of Alphonse Lavallée (A) and Crimson Seedless (B) cultivars as affected by rootstock use and sustained water deficit. (FI: full irrigation, DI: deficit irrigation). Vertical bars indicated by different letters identify significantly different means (P < 0.05, LSD).

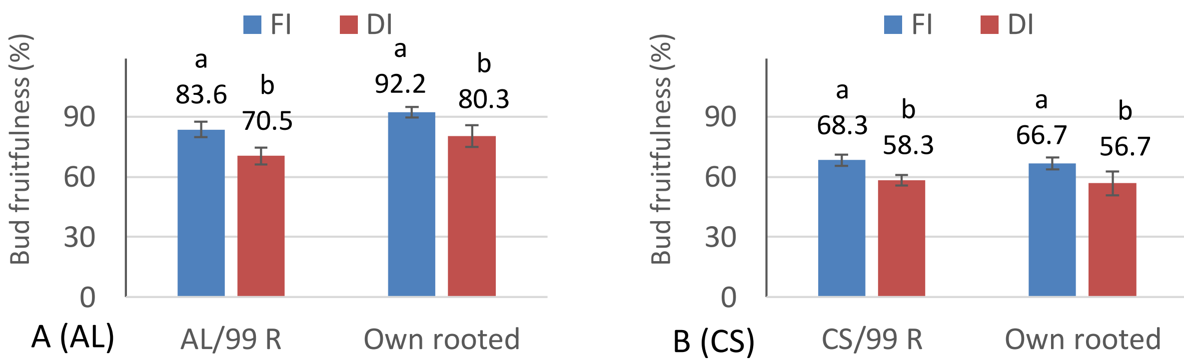

Figure 4. Bud fruitfulness of Alphonse Lavallée (A) and Crimson Seedless (B) cultivars as affected by rootstock use and sustained water deficit. (FI: full irrigation, DI: deficit irrigation). Vertical bars indicated by different letters identify significantly different means (P < 0.05, LSD).

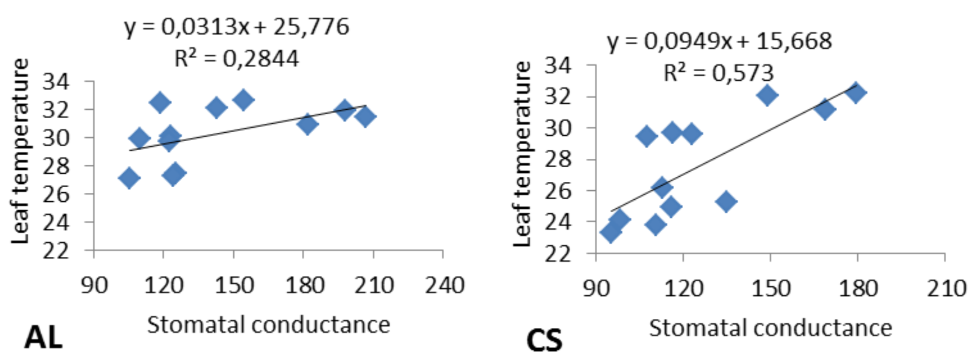

Figure 5. Relationship between leaf temperature and stomatal conductance of cultivars.

the world were considered although the differences were statistically significant. Sunlight and temperature are known as the most important climatic factors for inflorescence induction and differentiation. Most studies have considered these two factors independently by statistically correlating historical weather data during bud development with counts of inflorescences. In the present study, we have investigated the effect of mild stress emerging from water deficit (50% of field capacity level) on frutifulness of grapevines.

Correlations of g_s and T_{leaf} in grapevine cultivars are depicted in Figure 5. The g_s significantly responded to T_{leaf} in both cultivar, although the correlation coefficients were different for cultivars (R^2 = 0.284 and 0.573 for

Alphonse Lavallée and Crimson Seedless cultivars, respectively). This finding indicated the significant influence of T_{leaf} on leaf g_s as previously indicated by different studies on grapevines (Sabir and Yazar, 2015) and forest trees (Urban *et al*., 2017). As global mean temperatures rise and temperature extremes become more severe and frequent, understanding the impact of temperature on g_s, and modeling that relationship will become increasingly essential to cope with stress condition. Our results conclusively demonstrated that there is a direct positive response of g_s to increasing T_{leaf} in two grapevine cultivars. But such response was cultivar-depended with a stronger response of Crimson Seedless cultivar. This might be probably related with genotypic differences in leaf morphology, xylem structure, and physiology as stated by Sabir (2016b). The interplay between T_{leaf} and g_s suggest that it could contribute to differences in behavior among species in the predicted future climate.

CONCLUSION

Temperature extremes along with water scarcity forced the researchers to develop sustainable strategies such as deficit irrigation. However deficit irrigation strategy should be adopted for different genotypes under various growth conditions. The present experiment, conducted on grafted or non-grafted grapevines of Alphonse Lavallée and Crimson Seedless under glasshouse condition, revealed that the responses of two grapevine cultivars to contrasting irrigation levels significantly differed. Rootstock use and deficit irrigation markedly affected the physiology and fruitfulness of grapevines. Findings demonstrated that there is a direct positive response of stomatal conductance to increasing leaf temperature in two grapevine cultivars. But such response was cultivar-depended with a stronger response of Crimson Seedless cultivar. Overall results imply that use of appropriate rootstock may alleviate the adverse effect of water deficit on grapevines. Also, cultivars response differs according to the rootstock use.

REFERENCES

Corso M, Bonghi C (2014). Mini review: Grapevine rootstock effects on abiotic stress tolerance. Plant Sci. Tod. 1:108-113.

Düring H, Loveys BR (1996). Stomatal patchiness of field-grown Sultana leaves: Diurnal changes and light effects. Vitis 35:7-10.

Fereres E, Soriano MA (2007). Deficit irrigation for reducing agricultural water use. J. Exp. Bot. 58:147-159.

Johnson DM, Woodruff DR, Mcculloh KA, Meinzer FC (2009). Leaf hydraulic conductance, measured in situ, declines and recovers daily: leaf hydraulics, water potential and stomatal conductance in four temperate and three tropical tree species. Tree Physiol. 29:879-887.

Kounduras S, Tsialtas IT, Zioziou E, Nikolaou N (2008). Rootstock Effects on the Adaptive Strategies of Grapevine (*Vitis vinifera* L. cv. Cabernet–Sauvignon) under contrasting Water Status: Leaf Physiological and Structural Responses. Agric. Ecosyst. Environ. 128:86-96.

Miranda T, Ebner M, Traiser C, Roth-Nebelsick A (2013). Diurnal pattern of stomatal conductance in the large-leaved temperate liana Aristolochia macrophylla depends on spatial position within the leaf lamina. Ann. Bot. 111:905–915.

Okamoto G, Kuwamura T, Hirano K (2004). Effects of Water Deficit Stress on Leaf and Berry ABA and Berry Ripening in Chardonnay Grapevines. Vitis 43:15-17.

Palliotti A, Cartechini A (2005). Respiration activity in different above-ground organs of *Vitis vinifera* L. in response to temperature and developmental stage. Acta Hortic. 689:159-165.

Sabir A (2013). Improvement of grafting efficiency in hard grafting grape Berlandieri hybrid rootstocks by plant growth-promoting rhizobacteria (PGPR). Sci. Hort. 164:24-29.

Sabir A (2016a). Vegetative and reproductive growth responses of grapevine cv.' Italia' (*Vitis vinifera* L.) grafted on different rootstocks to contrasting soil water status. J. Agric. Sci. Tech. 18:1681-1692.

Sabir A (2016b). Physiological and morphological responses of grapevine (*V. vinifera* L. cv. 'Italia') leaf to water deficit under different rootstock effects. Acta Sci. Pol. Hortorum Cultus. 15:135-148.

Sabir A, Dogan Y, Tangolar S, Kafkas S (2010). Analysis of genetic relatedness among grapevine rootstocks by AFLP (Amplified Fragment Length Polymorphism) markers. J. Food Agric. Environ. 8 (1):210-213.

Sabir A, Sahin Z, Kara Z (2017). Variable response of leaf temperature, tissue density and greenness of 'Michele Palieri' (*Vitis vinifera* L.) grapevines to water stress under different rootstock effects. Selcuk J. Agric. Food Sci. 31(3):52-57.

Sabir A, Yazar K (2015). Diurnal dynamics of stomatal conductance and leaf temperature of grapevines (*Vitis vinifera* L.) in response to daily climatic variables. Acta Sci. Pol. Hortorum Cultus 14:3-15.

Satisha J, Prakash GS, Venugopalan R (2006). Modeling of the effect of physio-biochemical parameters in water use efficiency of grape varieties, rootstocks and their stionic combinations under moisture stress conditions. Turk. J. Agric. For. 30:261-271.

Urban J, Ingwers MW, McGuire MA, Teskey RO (2017). Increase in leaf temperature opens stomata and decouples net photosynthesis from stomatal conductance in Pinus taeda and Populus deltoides x nigra. J. Exp. Bot. 68(7):1757-1767.

Zufferey V, Cochard H, Ameglio T, Spring JL, Viret O (2011). Diurnal cycles of embolism formation and repair in petioles of grapevine (*Vitis vinifera* cv. Chasselas). J. Exp. Bot., DOI:10.1093/jxb/err081.