

## Vegetative and Reproductive Growth Responses of Grapevine cv. 'Italia' (*Vitis vinifera* L.) Grafted on Different Rootstocks to Contrasting Soil Water Status

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### ABSTRACT

Plant growth and reproductivity of grape cv. 'Italia' subjected to two different irrigation levels in controlled glasshouse were investigated over 2 years. Initially, two years old vines were grafted on 5 BB (*V. berlandieri* Planch.×*V. riparia* Michx.), 99 R (*V. berlandieri* Planch.×*V. rupestris* Scheele) rootstocks or on its own root system in 40 L pots. During the cultivation, half of the vines of each experimental group were Fully Irrigated (FI: 100% of field capacity) while the others were subjected to continuous Deficit Irrigation (DI: 40% of field capacity). During the study, significant negative effects of DI on plant vegetative development and physiology were observed. The lignified shoot length of vine on 5 BB rootstock decreased by 29.1% under DI as compared to growth under FI. On the other hand, the vine with 99 R rootstock decreased by 18.2% under DI as compared to lignified shoot growth under FI, while a 20.1% decrease occurred for own root (DI vs. FI). Also, DI regime resulted in slight decreases in P, K, and Ca status of leaves, while Zn and Cu concentrations were significantly higher in the vines subjected to DI. DI resulted in reduced cluster weight and vine yield in varying degrees with respect to rootstock usage. Under DI condition, the vines on 99 R yielded better than those on 5 BB, but vines on 5 BB reacted adversely to DI. Considering the overall findings, grapevines cv. 'Italia' on 99 R exhibited higher drought tolerance than 5 BB. Rootstocks had slight impairing effects on physiological traits, yield, and mineral acquisition of grapevine cv. 'Italia' as compared to own-rooted.

**Keywords:** Grapevine, Deficit irrigation, Rootstock, *Vitis* spp.

### INTRODUCTION

Irrigated agriculture is the primary user of diverted water globally, reaching a proportion that exceeds 80% of total available surface water in the arid and semi-arid zones (Feres and Soriano, 2007). Climate change combined with population growth is likely to intensify current challenges on agricultural water management (de Salvo *et al.*, 2013; Garcia-Tejero *et al.*, 2014). In the world, a large proportion of vineyards are located in regions faced with drought (e.g. Mediterranean-type climates) where atmospheric and soil water scarcity,

accompanied by high temperature, exert large constraints on grape yield and quality (Chaves *et al.*, 2010). Furthermore, the frequency of extreme events due to global warming is predicted to increase (Kuster *et al.*, 2013). Thus, the great challenge for the future decades will be the task of maximizing food production with less irrigation water, especially in regions having limited water resources (Mushtaq *et al.*, 2013). Selection of adapted plant genotypes (Mena *et al.*, 2012; Rasoli *et al.*, 2015) and a precisely managed irrigation schedule (Hamzei and Soltani, 2012) are examples of adaptive management to address future

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water shortages in agriculture due to a changing climate and competing demands.

Deficit irrigation is an irrigation regime whereby water supply is reduced and mild stress is allowed with minimal impacts on plant development. Under deficit irrigation, the plant is exposed to a certain level of water stress either during a particular period or throughout the whole growing season to maximize Water Use Efficiency (WUE) for higher yields per unit of irrigation. The expectation is that any yield reduction will be insignificant compared with the benefits gained through conserved water. In Australia, the use of regulated deficit irrigation [RDI, the reduction of irrigation water to predetermined levels at certain developmental stages (Aragüés *et al.*, 2014)] has been used to control vegetative growth and improve the consistency of grape production and quality (Goodwin and Jerie, 1992). DI techniques have been widely used in wine grapes (Okamoto *et al.*, 2004; Kounduras *et al.*, 2008; Romero *et al.*, 2013), although there are limited available data on table grapes, except for a few studies recently published (Faci *et al.*, 2014). Studies undertaken on deficit irrigation regime in grapes highlighted the need for particular adjustments in soil moisture values to control irrigation depending on rootzone depth (Goodwin and Jerie, 1992), soil texture (Tramontini *et al.*, 2013) and microclimatic changes (Baert *et al.*, 2013).

The grapevine rootstock genotypes greatly vary in physiological response to water scarcity (Kounduras *et al.*, 2008; Pavlousek, 2011), as currently used rootstock genotypes were derived from various American *Vitis* species (Sabir *et al.*, 2010). A drought-tolerant rootstock would be welcomed as many vineyards around the world lack suitable or adequate quantities of irrigation water. Previously, McCarthy *et al.* (1997) indicated that the yield response of wine grape 'Shiraz' to water deficits varied according to rootstock. In the absence of irrigation, the vines on either own root or grafted on Ramsey gave the highest yield, while the vines grafted to the rootstocks 110

R, K51-40, 110 3P and Freedom yielded poorly. For this reason, reliable knowledge on specific responses of grapevines under different scion/rootstock combination plays a pivotal role in productive and sustainable viticulture under limited water. Therefore, the main aims of this study were: (a) To investigate physiological and growth responses of grafted and own-rooted cv 'Italia' potted vines to contrasting irrigation regime; (b) To compare vine growth changes under the effect of the use of world widely popular rootstocks 5 BB (known as theoretically less adapted to limited water conditions) and 99 R (theoretically qualified as drought tolerant) (Galet, 1979), and (c) To analyze whether the rootstocks usage impair the growth of 'Italia' grapes in comparison with own-rooted vines.

## MATERIALS AND METHODS

### Plant Materials and Growth Condition

Experiments were carried out in the research and implementation glasshouse of Selcuk University, Konya, Turkey, during the 2011 and 2012 seasons. The 'Italia' 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 'Italia' on Kober 5 BB (*V. berlandieri* Planch. x *V. riparia* Michx.), Richter 99 (99 R; *V. riparia* Mich x *V. rupestris* Scheele) or grown as own roots. At the beginning of the first experimental year, two years old vines grown in equal-sized pots were selected on the basis of homogeneity in growth. Treatments were replicated three times in randomized blocks, with four vines per replicate. For two consecutive years, vines were grown under controlled glasshouse conditions. The first group of this cultivar was cultivated on 5 BB (*Vitis berlandieri* x *V. riparia* hybrid, which is commonly known as theoretically less

adapted to limited water conditions), while the second group was on 99 R (*V. berlandieri* × *V. rupestris* theoretically qualified as drought tolerant) (Galet, 1979). The final third one was own-rooted 'Italia' vines. The vines were individually cultivated in 40 L (solid volume) pots (35 cm diameter, 35 cm height) filled with sterile peat (1.034% N, 0.94% P<sub>2</sub>O<sub>5</sub>, 0.64% K<sub>2</sub>O, pH 5.88, Klassman®) 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. In the second year, while the vines in the fourth year life, they were pruned to three buds (subsequently three shoots) per vine. The shoots were tied with thread to wires 2.5 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. 20 g N, 12 g P, 20 g K, and 1.5 g Fe chelate per vine) from April to July.

### Scheduling and Achieving the Irrigation Regimes

Two types of irrigation regimes, i.e. Full Irrigation (FI) and continual Deficit Irrigation (DI), were applied to the vines. Irrigations were regulated according to soil water matric potential ( $\Psi_m$ ) levels using tensiometers (The Irrometer Company, Riverside, CA) placed at a depth of 20 cm and approximately 12 cm from the trunk, and were applied from bud break (early March) to the end of vegetation period (beginning of October) for two consecutive years. Field capacity levels were calculated in order to verify the accuracy of tensiometers for measuring 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 plastic bucket was measured and was subtracted from total amount of water applied initially (Satisha *et al.*, 2006). The obtained value was considered as the volume of the irrigation water that has to be applied to attain 100% field capacity (FI). 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  $\Psi_m$  following the slightly modified procedure described by Myburgh and van der Walt (2005). Changes in  $\Psi_m$  were continuously monitored with daily readings at around 13:00 pm as well as before and after irrigations (Okamoto *et al.*, 2004). To ensure the uniformity of irrigation, the water was transported directly into the pots by micro-irrigation systems consisting of individual spaghetti tubes. Repeated readings during several days showed that the tensiometers readings at midday (13.00 pm) were constantly around 0.8-12 kPa (centibars) and 36-44 kPa for FI and DI conditions, respectively. For DI, irrigation was started when  $\Psi_m$  reached 44 kPa and was terminated when the calculated amount of water was applied to ensure 40% of field capacity. The start value of irrigation system for FI group vines was adjusted to 12 kPa to ensure that the full water amount of field capacity was given. Relatively higher air temperature in the glasshouse was kept to simulate the typical semi-arid Mediterranean climate. During vegetation periods (15 March-30 October) for two experimental years, daily air temperature and relative humidity, recorded using data logger (Ebro EBI 20 TH1) inside the glasshouse, were 25-38°C and 33-55%, respectively. During the hot and dry summers in both years (from the beginning of June to September), excessive heat accumulation in glasshouse was avoided by opening the roof and sidewall windows as well as slight whitewash painting (providing approx. 30% light



reflection) to keep clusters and young leaves from burning. Under this condition, the instantaneous light intensity inside and outside the glasshouse was 37,330 and 53,330 lux (Lutron LX-105) at 13:00 pm.

### Shoot Growth Parameters

In the first experimental year, all the plants had single shoots. But, in the second year, the vines had three shoots and, thus, the total values of length and weight parameters of all the shoots were recorded. Measurements on total shoot length (with a sensitivity of 1 mm), lignified shoot (cane) length and lignified shoot percentage (percent of the scion shoot where complete lignification occurred), internode length, shoot diameter (measured by digital calipers at 1 cm above the second node), leaf (node) number per shoot, total shoot fresh weight ( $\text{g plant}^{-1}$ ), and total shoot dry weight ( $\text{g plant}^{-1}$ ) were performed when the shoots elongation was approaching cessation at the end of the vegetation period (Sabir *et al.*, 2012). After obtaining the fresh weight, shoot dry weights were determined at 70°C for 72 hours to a constant weight. A total of six plants (half of each experimental group) were used for shoot fresh and dry weight measurements while the rest were left for cane (lignified shoot) investigations later.

### Nutrient Element Analyses

For macro- and micro-elements analyses, the leaf blade samples of just-matured leaves were collected, dried, and ground. Quantitative multi-element analysis was performed by inductively coupled plasma optical emission spectrometry (Vista-Pro Axial, Varian Pty Ltd, Mulgrave, Australia) (AOAC, 1970). Element analysis results were checked using certified standard reference materials obtained from the National Institute of Standards and Technology (Gaithersburg, MD, USA).

### Cane Water Content

Cane water content was determined at the end of the growth seasons after shoot lignification. The total sample per plot consisted of cane lengths from upper, middle, and lower canes collected from nine grapevines, respectively. Cane samples were obtained by cutting ca. 50 mm cane lengths with a bud in its centre. Mean value of upper, middle, and lower canes was used. Cane fresh and dry masses were attained using the same procedure followed in the shoot. Water content of the fresh cane samples was calculated as the percentage water loss using the following equation (Myburgh and van der Walt, 2005);

$$\% \text{ Water} = (\text{Fresh mass} - \text{Dry mass}) / \text{Fresh mass} \times 100$$

### Reproductive Development

In the second growth season of the experiment, reproductive developments of grapevines were investigated between the budbreak and harvest. Vines were pruned back just before the beginning of the second experimental year, leaving three winter buds per plant. After budbreak and subsequent two-month-shoot development, cluster number per plant was recorded. Berry set was calculated by counting the total flower buds before bloom and the total number of berries two weeks after full bloom on 12 random clusters per treatment. Grapes were harvested between 17<sup>th</sup> and 25<sup>th</sup> July from the nine chosen vines per treatment when total soluble solids in berry juice reached ca. 17°Brix. Grapevine fertility (yield) was quantified at harvest by measuring total grape mass per plant (Myburgh and van der Walt, 2005). After weighing the clusters, a subsample of 200 berries was randomly taken from the clusters of each experimental group in order to determine the individual Berry Weight (BW) (Kounduras *et al.*, 2008).

## Statistical Analysis

Differences between the years for all parameter collected over two experimental years were not significant. Therefore, they were averaged before statistical analyses in order to avoid redundancy. Reproductive development investigations were carried out for only the second year as the vine yield was poor in the first year. All data were subjected to the variance analyses using SPSS 13.0 for Windows (SPSS Inc., Chicago, IL, USA) at  $P \leq 0.05$  level. The mean values were compared using the Least Significant Difference (LSD) test. Significant differences among rootstock $\times$ irrigation were presented in figures, while rootstock or treatment effects were evaluated in tables when the interactions showed no significant differences.

## RESULTS

### Shoot Growth

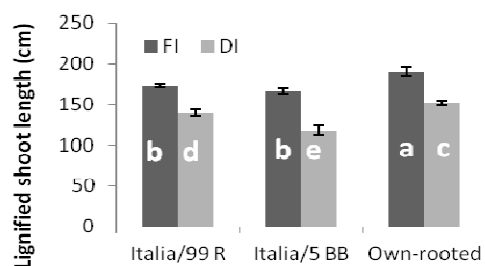
Two year measurements on shoot growth of the vines have been averaged and

presented in Table 1. According to the combined data, total shoot length was significantly affected by treatments and rootstock usage, while rootstock  $\times$  irrigation interaction was not significant. In response to Deficit Irrigation (DI), the highest decrease in total shoot length occurred in grapes cultivated on 5 BB [17.2% reduction from 223.2 cm (FI) to 184.8 cm (DI)], and followed by 99 R [16.3% reduction from 248.0 cm (FI) to 207.4 cm (DI)], while the smallest decrease was found in own-rooted vines (13.9%). Significant differences in lignified shoot lengths were observed among rootstocks $\times$ treatment combination (Figure 1-A). Cane evaluation during early September in both years showed that the lignified lengths of shoots in 'Italia'/5 BB vines were 166.5 and 118.0 cm for FI and DI, respectively, with a 29.1% decrease due to DI. The 'Italia'/99 R vines had more lignified nodes than 'Italia'/5 BB vines among DI groups. Percent decreases between FI and DI in the lignified lengths were 18.2% and 20.1% for 'Italia'/99 R and own rooted vines, respectively. Differences among the treatments with respect to fresh weight, dry

**Table 1.** Shoot development response of own-rooted or grafted 'Italia' grape to different irrigation levels and rootstock.<sup>a</sup>

Grafts or own root		Total shoot length (cm)	Percent lignified shoot (%)	Total fresh weight (g plant <sup>-1</sup> )	Total dry weight (g plant <sup>-1</sup> )	Diameter (mm)	Internode length (cm)
'Italia'/99 R	FI <sup>a</sup>	248.0 a	69.8	180.4 a	62.1 a	7.76 a	5.70
	DI <sup>b</sup>	207.4 b	67.5	118.0 b	45.1 b	7.13 b	5.51
	LSD ( $P \leq 0.05$ )	11.50	ns <sup>c</sup>	12.58	2.28	0.28	ns
'Italia'/5 BB	FI	223.2 a	74.7 a	176.4 a	54.9 a	6.85 a	6.01
	DI	184.8 b	69.4 b	119.7 b	42.9 b	6.17 b	5.76
	LSD ( $P \leq 0.05$ )	12.15	6.94	13.58	6.88	0.15	ns
'Italia'/Own root	FI	252.7 a	75.5	184.6	57.3 a	7.97	6.16
	DI	217.7 b	70.1	113.5	46.1 b	7.55	6.14
	LSD ( $P \leq 0.05$ )	14.97	ns	15.58	5.46	ns	ns
Rootstocks							
	99 R	227.7 a	68.6	146.1	53.6 a	7.45b	5.60 b
	5 BB	204.0 b	72.0	148.0	48.9 b	6.51c	5.89 ab
	Own root	235.2 a	72.8	149.0	51.7 ab	7.76a	6.15 a
	LSD ( $P \leq 0.05$ )	9.20	ns	ns	3.71	0.22	0.43

<sup>a</sup> Full Irrigation; <sup>b</sup> Deficit Irrigation, <sup>c</sup> Not significant. <sup>d</sup> Means were combined over two sampling years (n = 12). Mean values indicated by different letters identify significantly different groups ( $P \leq 0.05$ , LSD test).



**Figure 1.** Changes in lignified shoot length (cm) as affected by irrigation level (FI: Full Irrigation, DI: Deficit Irrigation) and rootstock. Values of bars indicated by different letters identify significantly different groups ( $P \leq 0.05$ , LSD test). Error bars represent standard errors.

weight, and diameter of shoots were also significant, although treatment x rootstock effects were insignificant.

### Macro and Microelement Acquisition

Generally, DI regime resulted in slight decreases in P, K, and Ca macroelement nutrient status of leaves, with exception in own-rooted 'Italia' where slight increments

occurred in P and Ca (Table 2). In contrast, Zn and Cu micro element concentrations were persistently higher in the vines subjected to DI. Generally, the water stress maintained in this study did not result in great fluctuations in macro element concentrations of the vines.

### Cane Water Content

DI treatment significantly reduced the cane water content determined as the mean value of basal, middle, and upper nodes lengthwise of the summer shoots of each plant (Figure 2). Considering the mean values obtained from three separate nodal parts of each vines, the highest decrease in cane water content in response to DI was determined in 'Italia'/5 BB (14.12%) vines while own-rooted vines had the lowest value (5.1%). Among the rootstocks, decrease in cane water content of vines on 99 R (7.78%) was considerably lower than those on 5 BB.

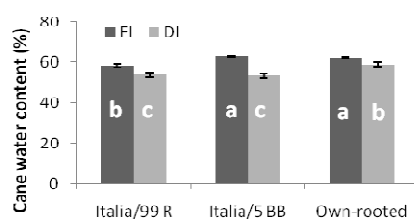
### Reproductive Growth

Statistically significant differences were

**Table 2.** Mineral acquisition response of own-rooted or grafted 'Italia' grape to different irrigation levels and rootstock.<sup>a</sup>

	Treat <sup>b</sup>	Macro (g kg <sup>-1</sup> )				Micro (mg kg <sup>-1</sup> )				
		P	K	Ca	Mg	Fe	Zn	Mn	B	Cu
'Italia'/99 R	FI	0.30a	1.31b	1.74b	0.37	271.2a	18.2a	38.1bc	64.1a	2.37c
	DI	0.28a	1.30b	1.71b	0.36	241.0c	18.6a	37.0c	60.0b	2.75b
'Italia'/5 BB	FI	0.23cd	1.34c	1.47c	0.38	176.3d	15.4b	45.5a	41.3e	1.73d
	DI	0.25b	1.28c	1.41c	0.39	181.7d	18.9a	41.1b	43.8e	2.40c
Own root	FI	0.22a	1.71b	1.72b	0.29	250.6b	15.7b	41.0b	55.4c	2.30c
	DI	0.24bc	1.69a	1.85a	0.28	264.3a	19.1a	45.8a	49.4d	3.54a
99 R <sup>c</sup>	FI	0.29A	1.31B	1.73A	0.36A	256.1A	18.4	37.5B	62.1A	2.56B
	DI	0.24B	1.31B	1.44B	0.38A	179.0B	17.2	43.3A	42.6C	2.06C
Own root <sup>c</sup>	FI	0.23C	1.70A	1.79A	0.29B	257.5A	17.4	43.4A	52.4B	2.92A
	DI	0.24C	1.69A	1.85A	0.28B	264.3A	19.1A	45.8A	49.4D	3.54A
Treatment		ns	ns	ns	ns	ns	1.11	ns	3.75	0.16
Rootstock		0.013	0.080	0.067	0.035	5.40	ns	2.32	2.15	0.20
Interaction		0.018	ns	0.086	ns	7.64	1.93	3.28	2.65	0.28

<sup>a</sup> Means were obtained from leaf blades over two sampling years (n= 12). Mean values indicated by different letters on each column, identify significantly different groups ( $P \leq 0.05$ , LSD test); <sup>b</sup> FI: Full Irrigation; DI: Deficit Irrigation, ns: Not significant, <sup>c</sup> Means on rootstocks/own root vines are depicted with capital letters.



**Figure 2.** Changes in cane water content (%) as affected by irrigation level (FI: Full Irrigation, DI: Deficit Irrigation) and rootstock. Values of bars indicated by different letters identify significantly different groups ( $P \leq 0.05$ , LSD test). Error bars represent standard errors.

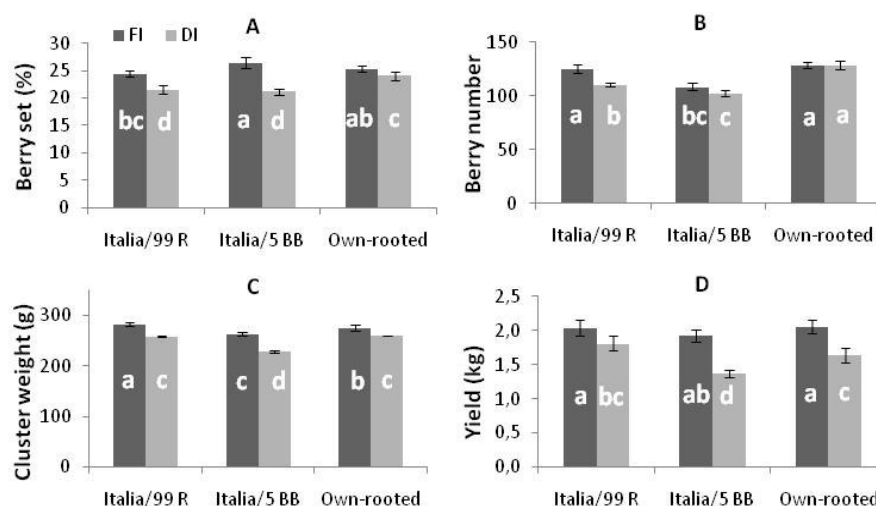
found among rootstock  $\times$  treatment interactions for berry set (%), berry number per cluster, cluster weight (g) and yield per vine (kg) (Figures 3-A, -B, -C, -D). DI significantly decreased the yield and yield components of 'Italia' cultivar, except for berry number for only own-rooted vines. Among the rootstocks, comparing the berry set values of FI and DI treatments between the rootstocks, the highest decrease (19.6%) in berry set in response to DI was observed in 'Italia/5 BB (from 26.4 to 21.2%), while DI resulted in 11.9% diminish (from 24.5 to 21.6%) in 'Italia/99 R. The smallest

decrease in berry set percentage occurred among the own-rooted vines (from 24.6 to 24.0% berry set percentages with 2.3% decrease). Berry number per cluster did not significantly change among water treatments when the vines were cultivated on its own roots. However, it decreased in response to the DI at varying levels depending on the rootstock usage. Average values of cluster weight and yield were significantly lower across DI-subjected vines than those of FI treatments. Similar to rootstock-dependent changes in berry set and berry number parameters, decrease rates in cluster weight and yield parameters were markedly lower in 'Italia/99 R vines than those of 'Italia/5 BB vines. Differential responses were found about the reproductive growth of 'Italia' vines depending on the rootstocks.

## DISCUSSION

### Canopy Growth

The pooled data over two consecutive experimental years revealed that DI restricted the canopy growth of 'Italia' grapevine cultivar. Such decreases occurred



**Figure 3.** Changes in berry set (A), berry number per cluster (B), cluster weight (C), and yield per vine (D) as affected by irrigation level (FI: Full Irrigation, DI: Deficit Irrigation) and rootstock. Values of bars indicated by different letters identify significantly different groups ( $P \leq 0.05$ , LSD test). Error bars represent standard errors.



with respect to the use of different root systems. Recently, Cramer *et al.* (2007) have well observed that, under conditions of a relatively moderate water deficit, the elongation of grapevine shoots decreased. From the results of the present and previous studies, the growth of annual shoots represents a sensitive indicator for water status in grapevine plants (Dry *et al.*, 2000; Pavlousek, 2011). Nevertheless, a low shoot growth rate does not necessarily indicate that the physiological capacity of the vine is low. As stated by Dry and Loveys (1998), the capacity of a vine refers to the total yield rather than to the activity rate such as total vegetative growth. According to the mean data obtained from the two years, rootstocks differently affected the shoot total length and diameters of scion shoots, with the highest values obtained from own-rooted vines. Among the rootstocks, such parameters were generally higher in vines cultivated on 99 R (*Berlandieri x Rupestris*) than those on 5 BB (*Berlandieri x Riparia*). The effect of 99 R on the shoots of the scion cultivar was well adjusted to the previous reports (Koundouras *et al.*, 2008) where significantly higher scion growth on *Berlandieri x Rupestris* rootstock was reported compared to those on *Berlandieri x Riparia*.

### Nutrient Acquisition

In the present study, deficiency in irrigation did not markedly impair macro element status of leaf blades across the vines. In contrast, the concentrations of certain micro elements, such as Zn, B, and Cu, decreased under DI condition. On the other hand, the rootstocks had significant effect on nutrient concentrations measured in 'Italia' leaf blades. Leaf P and B concentrations were significantly higher in 'Italia'/99 R vines than the others. On the other hand, K acquisition of own-rooted vines was markedly higher than the others. The rootstock 5 BB displayed a slight negative influence on Ca, Fe, B, and Cu

concentrations of leaves. Nonetheless, all macro- and micro-nutrient concentrations in leaf blades fell within a range considered to be healthy for wine grapes (Gärtel, 1996). This verifies the good mineral acquisition potential and well-developed complex mechanisms of grapevines to survive under water constrain as previously stated by Tramontini *et al.* (2013). Effects of warming and drought on nutrient element uptake of grapes have been investigated in several studies independently of each other, whereas interactions between genotype and water deficit are less well known. Studies imply that drought and heat resistance will become important for plant survival, particularly together with additional stress by competition with other plants for light, water, and nutrient elements (Kuster *et al.*, 2013). In this study, relatively higher mineral uptake of 99 R, compared with 5 BB, may indicate more competitive mineral acquisition aptitude of 99 R under water deficit condition.

### Water Content of Canes

The higher water content in 'Italia' canes on 99 R might most likely be related with its higher tolerance aptitude to water shortage. This case is in accordance with the results of a recent study in which 99 R was reported with its distinguished effect on increase in water-use efficiency during critical growth stages (Satisha *et al.*, 2010). Specifically, the healthy formation of buds of basal nodes might be more important than others, as genetically 'Italia' cultivar has fruitful basal nodes. Water stress during early shoot development may result in reduced canopy development and, consequently, insufficient leaf area to adequately support fruit development and maturation. Because physiological initiation of clusters at nodes 1-4 for the following season begins about two weeks before full bloom and continues for about two weeks, severe water stress during this stage reduce the following season's fruitfulness (Celette and Gary,



2013). The major influence at that phenological stage is known to be a decrease in the cluster number per shoot and not the number of flowers per cluster, which develop later in the season and throughout the dormant season. In accordance with the mentioned facts, cluster features in this study were negatively affected by DI.

### Yield and Quality

Shoot development, which normally continues fast during early stage of vegetative development, would be reduced by water stress (Romero *et al.*, 2013). Therefore, severe restriction in canopy development due to water scarcity will limit the photosynthetic capacity of the vine and may restrict cluster development. Further water deficit between bloom and *veraison* (onset of maturity) has been earlier shown to reduce flower induction for the next season (Guilpart *et al.*, 2014). Decreases in berry set investigated in this study and previous reports suggested that low soil water content at floral primordia in early summer might induce poor bunch differentiation and also cause bunch abortion (Myburgh, 2003), although its magnitude was rootstock-dependent. The literature illustrations including the present results indicated that vines at distinct growth stages may handle different levels of water stress. Cluster weight and vine yield were reduced by DI in varying degrees with respect to rootstock usage. When the rootstock comparison is considered for viticulture in phylloxera (*Viteus vitifoliae*) infected area, under DI condition, the vines on 99 R (*Berlandieri*×*Rupestris*) yielded better, but vines on 5 BB (*Berlandieri*×*Riparia*) reacted adversely to DI. The better performance of 99 R and also the poor performance of 5 BB under DI condition, prove the suggestion by Galet (1979) and Koundouras *et al.* (2008) who classified the *Berlandieri*×*Rupestris* group as drought tolerant and the *Berlandieri*×*Riparia* as drought sensitive.

### CONCLUSIONS

Considering the overall investigations, DI affected the canopy growth, vine physiology, cane water content, nutrient elements status, and fruitfulness of 'Italia' grape cultivar in varying levels according to the rootstocks. Physiological response of grapes to different soil water status during the study indicated that the DI plants were under moderate stress. Based on combined data over the two years, many growth parameters were better for own rooted vines in comparison to rootstock usage. However, considering the necessity of rootstock usage due to phylloxera invasion to the vineyards globally, the response of cultivar under rootstock effect is important for a better tolerance to water deficit. Negative effects of water limitation were more pronounced in 'Italia' vines cultivated on 5 BB rootstock, whereas the vines on 99 R displayed more tolerance to drought in terms of growth and physiology in comparison with 5 BB. Although the DI affected the vine vigor and physiology negatively, mineral uptakes across the grapevines were sufficient under water deficit effect. In viticulture areas where the available irrigation water supply limits production, deficit irrigation strategy will gain worldwide importance over time, as producers strive to increase the yield of their limited farmland and water resources. The findings presented here may be of great relevance in evaluating grape rootstocks for viticulture with limited irrigation conditions to achieve adequate yield and the quality standards. Under water deficit conditions, 99 R would be expected to achieve a more appropriate balance between vegetative and reproductive growth of table grape scion, although the same conclusion cannot be valid for wine grapes.

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## واکنش رشد سبزینه ای و زایشی انگور کولتیوار "ایتالیا" (*Vitis vinifera* L.) پیوند شده روی پایه های مختلف در شرایط متفاوت آب خاک

ع. صابیر

### چکیده

رشد و فیزیولوژی گیاه انگور کولتیوار "ایتالیا" تحت دو رژیم مختلف آبیاری در شرایط کنترل شده گلخانه ای در طی دو سال بررسی شد. در آغاز، تاک های دوساله روی پایه 5BB (*V. berlandieri*) و 99R (*V. berlandieri* Planch. x *V. riparia* Michx.) و تاک های Planch. x *V. riparia* Michx. و *rupestris* Scheele یا روی ریشه خود (own-rooted) در گلدان های 40 لیتری کاشته شدند. در طی دوره کاشت و رشد، نیمی از تاک ها در هر گروه آزمایشی به طور کامل آبیاری شد (با علامت FI به معنای 100٪ رطوبت ظرفیت زراعی) و نیمی دیگر همواره به صورت کم آبیاری (DI به معنای آبیاری در 40٪ ظرفیت زراعی). در طی این آزمایش، اثر های منفی معنی داری از تیمار کم آبیاری روی رشد سبزینه ای و فیزیولوژی تاک ها مشاهده شد. در تیمار کم آبیاری، طول ساقه لیگنینی شده تاک های پیوند شده روی پایه 5BB کاهش معادل 29/1٪ نسبت به آبیاری کامل نشان داد. از سوی دیگر، ساقه لیگنینی شده تاک هایی که روی پایه 99R بودند در کم آبیاری کاهش برابر 18/2٪ در مقایسه با آبیاری کامل نشان داد و این کاهش در مورد تاک های روی ریشه خودی برابر 20/1٪ بود. همچنین، تیمار کم آبیاری منجر به کاهش اندکی در N، K، و Ca برگ ها شد ولی غلظت Zn و Cu در تاک های کم آبیاری شده به طور معنی داری بیشتر بود. نیز، کم آبیاری منجر به درجات مختلفی از کاهش در وزن خوشه ها و عملکرد تاک ها از نظر کار برد پایه شد. در شرایط کم آبیاری، تاک های روی پایه 99 R عملکرد بهتری داشتند ولی تاک های روی پایه 5 BB واکنش منفی به کم آبیاری نشان دادند. با در نظر گرفتن نتایج کلی این آزمایش، می توان گفت که انگور کولتیوار "ایتالیا" روی پایه 99R نسبت به پایه 5BB مقاومت بیشتری به خشکی نشان داد. در مورد این کولتیوار، پیوند زدن روی پایه در مقایسه با "ریشه خودی" بر خصوصیات فیزیولوژیکی، عملکرد و جذب عناصر معدنی اندکی اثر منفی داشت.