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# Effect of Rootstock on Grafted Grapevine Quality

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**Summary**

As the home of numerous grape genotypes, Turkey is one of the major centers of viniculture genetic material in the world. 'Merzifon Karasi' (*Vitis vinifera* L.) is one of the most valuable red wine grape cultivars in Turkey. However, despite the variety's relative age, 'Merzifon Karasi' has yet to be tested on different rootstocks. Therefore, this study was conducted to determine the effects of different rootstocks on the growth characteristics of 'Merzifon Karasi' scion. Growth parameters (shoot length (cm), shoot diameter (mm), internode length (cm), total and unit leaf area ($cm^2$), root length (cm), root scale (0–4) and root number) were calculated and carbohydrate content (%) of the grafted grapevine shoots, trunk and roots analysed for 9 different rootstocks. Significant differences ($P < 0.01$) were found among rootstocks. 8B and Rupestris du Lot rated best in terms of root length, root scale and root number ($P < 0.01$). Highest shoot length, shoot diameter ($P < 0.01$) and internode length were obtained, respectively, with the 110R, 8B and Rupestris du Lot rootstocks ($P < 0.05$). Rupestris du Lot also produced the grapevines with the highest total leaf area per plant and main shoot, whereas the grapevines grafted on 8B had the highest unit leaf area ($P < 0.01$). Sugar, starch and carbohydrate contents (%) of the different plant parts also varied significantly by rootstock ($P < 0.01$), with the highest root carbohydrate content measured in the 5C (22.4 %) rootstock, and the highest trunk and shoot carbohydrate content measured in the 110R (12.1 and 13.4 %, respectively). In sum, the study found the best rootstocks for 'Merzifon Karasi' to be 8B, Rupestris du Lot and 110R in terms of root and shoot growth, whereas 'Merzifon Karasi' grape grafted onto 110R and 5C rootstock had the highest carbohydrate contents.

**Key words.** Rootstock – grafted grapevine – grapevine quality – carbohydrates

## Introduction

Grape rootstocks are of great importance for countries engaged in viticulture (Omer et al. 1999; Troncoso et al. 1999). Rootstocks have an effect on vine growth, productivity and the vegetative vigour of scions, thereby improving or reducing yield (Boselli et al. 1992; Ferroni and Scalabrelli 1995; Rizk-Alla et al. 2011; Verma et al. 2010; Jogaiah et al. 2013; Rafaat et al. 2013). Grafting of *Vitis vinifera* varieties onto resistant rootstocks represents the most effective way of protecting crops against phylloxera (Vršič et al. 2004), especially in phylloxera-contaminated areas, where the establishment of suitable vines on their own roots is virtually impossible. Choice of rootstock is one of the most important factors in the establishment of a vineyard, but given the availability of so many choices, identifying the most suitable rootstock for a particular scion is difficult (Loreti and Massai 2006). Reynolds and Wardle (2001) summarize the main criteria for choosing rootstocks as follows: phylloxera resistance, nematode resistance, adaptability to high pH soils, adaptability to saline soils, adaptability to low pH soils, adaptability to wet or poorly drained soils, adaptability to drought. According to Morton (1979), there is no such thing as a universal rootstock, making variety-specific research to identify the best rootstock a necessity.

Rootstock plays a role in the partitioning of biomass between root, shoot, trunk and fruit. Not only are carbohydrates stored in vine canes evidence of the health and vigor of the previous season's growth (Balasubrahmanyam et al. 1978), in many plant species, root carbohydrates are responsible for shoot development, growth in stem and root diameters as well as new root length, flower bud initiation and growth, and fruit set (Loescher et al. 1990).

Turkey is an important genetic center for grapevines, with close to 1.200 grape varieties (Ergül and Ağaoğlu 2001; Ergül et al. 2002; Uzun and Bayir 2008) and grown

on 472.545 ha vineyards producing 4.296.350 t of fresh grapes (Anonymous 2012).

'Merzifon Karasi,' one of the most valuable red-wine grape varieties in Turkey, has been grown for centuries in the district of Merzifon. Vineyards in this area are generally head-trained, spur-pruned and grown on their own roots using traditional methods. With an increasing understanding of the value of this variety, in recent years, modern vineyards have been established with grafted grapevines. 'Merzifon Karasi' has also been cultivated using trellis systems, but until now, the variety has not been tested on different rootstocks. Therefore, the aim of this study was to assess the impact of different rootstocks (99R, 110R, 5C, SO4, 140 Ruggeri, 8B, 5BB, Rupestris du Lot and 1103 Paulsen) on certain growth characteristics of 'Merzifon Karasi' scion.

## Materials and Methods

The study was carried out between 2010 and 2011 in Samsun, Turkey using 'Merzifon Karasi' (*Vitis Vinifera* L. cv.) as scion and 99R, 110R, 5C, SO4, 140 Ruggeri, 8B, 5BB, Rupestris du Lot and 1103 Paulsen as rootstocks. Rootstocks were introduced from the Tekirdag and Manisa Viticultural Research Station in February 2010 and stored at + 2 °C until use. Both rootstocks and scions were disinfected using Captan 50 % W.P. prior to grafting. Grafting was performed on 4 April 2010 and 3 April 2011 using the omega indoor grafting technique. Following callusing, on 11 May 2010 and 10 May 2011, grafted cuttings were planted in a nursery with clay-loam soil containing 2.99 % organic matter and a pH of 7.1. Nursery soil was covered with black plastic mulch to control weeds and retain heat and moisture, and plants were irrigated with a drip system. Primary leaf area on the main shoot, lateral leaf area on the lateral shoots and whole plant leaf area (main and lateral shoots) were measured at the end of August. Unit leaf area was determined by calculating the ratio of main shoot leaves to main shoot leaf area. Leaf area was determined non-destructively according to Elsner and Jubb (1988). Grafted grapevines were dug out after leaf drop, and shoot length (cm), shoot diameter (mm), internode length (cm), trunk diameter (mm) and root length (cm) were measured. Root scale and root number were measured in December at the end of the growing season. Root scale (0–4) was calculated according to Dardeniz et al. (2008) (Table 1).

Table 1. Root length, root scale and root number of 'Merzifon Karasi' cultivar grown on different rootstock genotypes.

| Rootstocks | Root length (cm) | Root scale (0–4) | Root number |
|---|---|---|---|
| 99 R | 21.8 b | 3.6 a | 19.3 a |
| 5 C | 23.7 b | 2.7 b | 12.3 b |
| 110 R | 27.4 ab | 2.7 b | 16.5 ab |
| 8 B | 31.4 a | 3.5 ab | 19.4 a |
| 5 BB | 24.0 b | 3.2 ab | 19.5 a |
| SO4 | 28.6 ab | 3.2 ab | 16.1 ab |
| Rupestris du Lot | 33.1 a | 3.6 a | 13.6 ab |
| 1103 Paulsen | 24.3 b | 2.9 ab | 19.9 a |
| 140 Ruggeri | 23.3 b | 2.7 b | 15.5 ab |
| Pooled SEM[z] | 0.516 | 0.063 | 0.484 |
| Rootstocks | ** | ** | ** |

[z]Pooled SEM: Pooled standard error of the means (* P < 0.05; ** P < 0.01).

### *Carbohydrate Analysis*

Samples of shoots, trunks and roots were collected from each grapevine in both years (Bates et al. 2002). Plant tissue samples were pulverized in a mill (IKA, Staufen, Germany) using a 40-mesh screen, and 200 mg of dust were used in extraction. Soluble sugars were extracted twice with 8 ml of 80 % ethanol at 60 °C for 30 min (Candolfi and Koblet 1990), and sugar content was determined using the anthrone method described by Scott and Melvin (1953). Starch was then extracted twice with 8 ml of 1 M perchloric acid at 60 °C for one hour, and starch content was measured using the same method. Absorbency readings were made at 620 nm with a spectrophotometer. Glucose was used as the standard for both soluble sugars and starch.

### *Statistical Analysis*

A randomized complete block design with 3 replications was used in both years. Growth characteristics and carbohydrate content were measured from four uniformly grown grafted vines per rootstock, and the mean measurements were calculated. Data analysis was performed using SPSS 16.0 for Windows. Means for 2010 and 2011 were calculated and analyzed using one-way ANOVA and Duncan tests, with differences among rootstocks considered significant at P = 0.05 and P = 0.01.

## Results

Data showed rootstock to affect root growth and development, with significant differences (P < 0.01) in root length, root scale and root number of grafted grapevines observed among rootstock genotypes (Table 1). Root length varied from 21.8 (99R) to 33.1 cm (Rupestris du Lot). Minimum root scale (2.7) was observed with the 140 Ruggeri, 110R and 5C rootstocks, and maximum root scale (3.6) was observed with the Rupestris du Lot and 99R rootstock genotypes. Interestingly, the 99R rootstock genotype had

the lowest root length as well as the highest root scale. Root number varied from 12.3 to 19.9, with the lowest root numbers observed with the 5C rootstock genotype and the highest with the 1103 Paulsen genotype, followed by the 5BB, 8B and 99R rootstocks.

Rootstock was also found to affect shoot growth, with significant differences observed in shoot length ($P < 0.01$), shoot diameter ($P < 0.01$) and internode lengths ($P < 0.05$) of grafted grapevines among rootstock genotypes (Table 2). The 110R rootstock had the longest shoot length (112.4 cm), followed by the 8B genotype (105.7 cm), whereas the 1103 Paulsen genotype had the shortest shoot length (57.5 cm). Overall, the 1103 Paulsen genotype showed the least vigorous scion development based on shoot length, shoot diameter and internode length, whereas the most vigorous scion development was observed in the 110 R, 8B and Rupestris du Lot rootstock genotypes.

Main shoot, lateral shoot, whole plant leaf area and main shoot unit leaf area of grafted grapevines were also found to vary significantly ($P < 0.05$, $P < 0.01$)) by rootstock genotype (Table 3). The 110 R and Rupestris du Lot genotypes had the highest main shoot total leaf areas (1556.5 $cm^2$ and 1468.5 $cm^2$, respectively), and the Rupestris du Lot genotype had the highest lateral shoot total leaf area (986.1 $cm^2$) as well as the highest whole plant leaf area (2445.3 $cm^2$). The 1103 Paulsen genotype had the lowest main shoot total leaf area (676.3 $cm^2$) and whole plant leaf area (1181.6 $cm^2$), and the 140 Ruggeri rootstock genotype had the lowest lateral shoot total leaf area (470.6 $cm^2$). The highest main shoot unit leaf area was observed in the 8B rootstock (46.6 $cm^2$) and the lowest in the 5C (26.1 $cm^2$) and 1103 Paulsen (25.7 $cm^2$) rootstocks. In general, the total leaf area of grafted grapevines was significantly higher with the more vigorous rootstocks (Rupestris du Lot, 110R, 8B) when compared to the less vigorous rootstocks (5C and 1103 Paulsen).

Table 2. Shoot length, shoot diameter and internodes length of 'Merzifon Karasi' cultivar grown on different rootstock genotypes.

| Rootstocks | Shoot Length (cm) | Shoot Diameter (mm) | Internodes Length (cm) |
|---|---|---|---|
| 99 R | 84.4 ab | 6.6 a | 3.2 ab |
| 5 C | 64.2 b | 5.5 bc | 3.4 a |
| 110 R | 112.4 a | 6.9 a | 3.7 a |
| 8 B | 105.7 a | 7.0 a | 3.9 a |
| 5 BB | 94.3 ab | 6.3 ab | 3.5 a |
| SO4 | 95.3 ab | 7.0 a | 3.7 a |
| Rupestris du Lot | 104.3 a | 6.8 a | 3.7 a |
| 1103 Paulsen | 57.5 b | 5.0 c | 2.7 b |
| 140 Ruggeri | 91.0 ab | 7.1 a | 3.6 a |
| Pooled SEM[z] | 2.885 | 0.091 | 0.068 |
| Rootstocks | ** | ** | * |

[z]Pooled SEM: Pooled standard error of the means (* $P < 0.05$; ** $P < 0.01$).

Carbohydrate (sugar + starch) content of grapevine parts (root, trunk and shoot) varied significantly among rootstock genotypes ($P < 0.01$). The highest root sugar concentration was found in the 99R (8.5 %) and 5BB (7.7 %) grafted grapevines, whereas the highest trunk and shoot sugar concentrations were found in the SO4 grafted grapevines (6.7 % and 7.8 %, respectively). In

Table 3. Some leaf area parameters of 'Merzifon Karasi' cultivar grown on different rootstock genotypes (in $cm^2$).

| Rootstocks | Total leaf area main shoot | Total leaf area lateral shoots | Whole plant leaf area main and lateral shoots | Unit leaf area main shoot |
|---|---|---|---|---|
| 99 R | 1140.8 ab | 373.4 d | 1514.2 de | 33.05 ab |
| 5 C | 1077.3 ab | 762.3 abc | 1839.6 bcd | 26.1 b |
| 110 R | 1556.5 a | 553.9 bcd | 2110.4 abc | 37.0 ab |
| 8 B | 1392.7 a | 856.4 ab | 2249.2 ab | 46.6 a |
| 5 BB | 1045.8 ab | 871.4 ab | 1917.2 abcd | 31.8 b |
| SO4 | 1064.3 ab | 627.5 bcd | 1691.8 cde | 39.8 ab |
| Rupestris du Lot | 1468.5 a | 976.8 a | 2445.3 a | 35.4 ab |
| 1103 Paulsen | 676.3 b | 505.3 bcd | 1181.6 e | 25.7 b |
| 140 Ruggeri | 1124.7 ab | 470.6 cd | 1595.3 cde | 36.9 ab |
| Poolen SEM[z] | 43.308 | 29.079 | 41.788 | 1.459 |
| Rootstocks | ** | ** | ** | * |

[z]Pooled SEM: Pooled standard error of the means (* $P < 0.05$; ** $P < 0.01$).

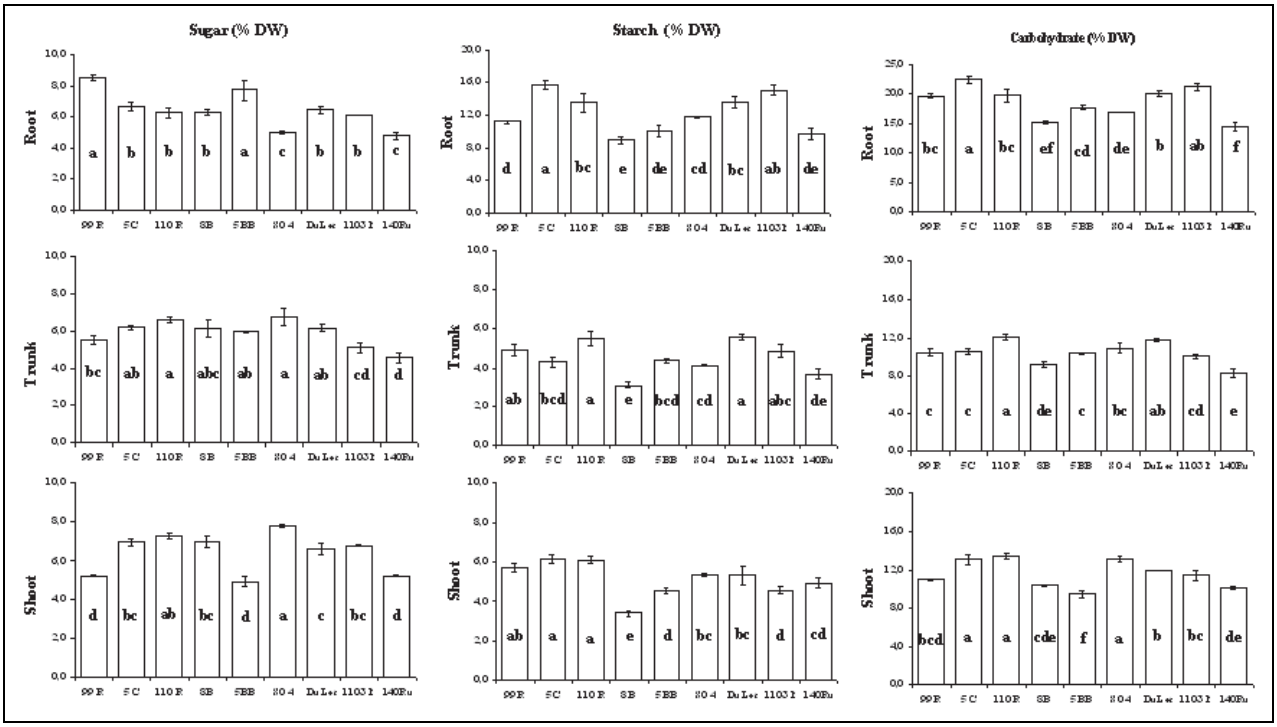



Fig. 1. Sugar, starch and carbohydrates (% dry weight) at roots, trunks and shoots of 'Merzifon Karasi' cultivar grown on different rootstock genotypes. [y]Means with different letters in the same column were significantly different ($P < 0.01$).

general, root and shoot sugar contents were found to be slightly higher than trunk sugar content (Fig. 1). The highest starch content was found in the 5C (15.7 %) grafted grapevines, the highest trunk starch content in the 110R (5.5 %) and Rupestris du Lot (5.6 %), and the highest shoot starch content in the 5C (6.1 %) and 110R (6.1 %) grafted grapevines. Overall carbohydrate (sugar + starch) concentrations of grafted vines were significantly affected by rootstock ($P < 0.01$). Root carbohydrate content was highest in the 5C (22.4 %) rootstock, whereas trunk carbohydrate content was highest in the 110R (12.1 %) grafts and shoot carbohydrate content was highest in the 110R (13.4 %), 5C (13.1 %) and SO4 (13.1 %) grafted vines.

## Discussion

The present study showed root length, scale and number to vary with rootstock genotype, with Rupestris du Lot, 8B and 99R performing best in terms of root length, root number and root scale characteristics. These results are similar to those reported by many studies. According to Daulta and Chauhan (1980), both the rootstock and the scion cultivar affect the zone and size of the root system. Root anatomy, morphology, development and distribution have also been found to differ among rootstock species (Richards 1983; Somkuwar et al. 2012). Rootstocks such as St. George, 110R, 140Ruggeri, 1103 Paulsen and 99R are known to possess strong, drought-tolerant root structures (Satisha et al. 2008), whereas root structures of SO4 and 5C genotypes are unable to tolerate drought conditions. Morano and Kliewer (1994) also reported the St. George genotype to have the greatest number of roots of the genotypes studies. Our study found that rootstocks with strong root structures also produced the most shoot growth. This is in line with Snyder and Harmon (1948), who reported vigorous rootstocks to produce the most wood in the first season of growth, whereas cultivars grafted on weaker rootstocks produced less wood, but performed fairly well in terms of fruit production. Although 1103 Paulsen has been reported to be of moderate-high vigor (Shaffer et al. 2004; Goldammer 2013), the present study found 1103 Paulsen to be less vigorous than the other rootstock genotypes tested. This finding could be attributable to the stock-scion interaction. As stated by Hartmann et al. (1993), a rootstock found to be useful for one cultivar may not be suitable for another, as vine performance is affected more by the interaction between stock and scion than by either stock or scion alone. In addition, a study by Tandonnet et al. (2010) reported that root development can be strongly impaired by scion type and that shoot development in young vines is affected more by scion than by rootstock.

Rootstock is known to affect starch and soluble sugar reserves of grapevines (Smith 2004). This study found carbohydrate reserves to vary among grapevine organs (Fig. 2), with significantly higher starch concentrations measured in roots when compared to other plant parts. The roots are the main storage organs for carbohydrate

reserves, and carbohydrates in the roots are generally used for growth (Bates et al. 2002; Holzapfel et al. 2009). Overall, this study found rootstock to influence the development of grapevines. According to the parameters tested, the 8B, Rupestris du Lot and 110R genotypes represented the best rootstocks in terms of growth and development of plant organs, whereas the highest carbohydrate contents were noted in the grapevines grafted on 110R and 5C rootstocks. Given that the interaction of stock and scion has a greater effect on vine performance than that of either stock or scion alone, no single rootstock can be said to be universally advantageous for all cultivars (Hartmann et al. 1993). In order to identify the most suitable rootstocks for the 'Merzifon Karasi' grape variety, long-term studies monitoring the effects of rootstock-scion interaction in vineyard conditions are required.

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