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The Effects of Rootstock-Scion Relationships on Yield and Quality in Grapevine cv. Ekşi Kara (*Vitis vinifera* L.)

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HIGHLIGHTS

- The nutrient uptake from the soil was at different levels when the Ekşi Kara grape variety was grown on its own roots and vine rootstocks (41 B, Rupestris du Lot and 110 R).
- Grape rootstocks affected the yield and quality characteristics of Ekşi Kara grape variety at different levels.

Abstract

Vineyards are usually established by grafting onto vine rootstocks. Vine rootstocks affect the grafted varieties directly or by environmental factors and by changing the physiology of rootstock and scion varieties. There may be great differences in mineral nutrition of grape rootstocks and grape varieties in grafted and nongrafted combinations. The choice of grape variety and vine rootstock for vineyard ecology is vital for the sustainability of viticulture, as they affect the mineral nutrient balances, biotic and abiotic stress tolerances, yield and product quality of grape rootstocks and grafted varieties, and these change with edaphic factors. This study was carried out in ~20 years old vineyards established with vines on their own roots of Ekşi Kara grape variety (Pollinator is Gök Üzüm), which is most used in production in Konya province, and seedlings grafted onto 41B, 110R and Rupestris du Lot rootstocks. The effects of rootstock and scion nutrition were searched. Yield per vine, cluster weight, cluster number, cluster length and cluster width data showed the highest values from vines on their own roots, while the order of grafted combinations changed according to the trait measured. While the differences between °Brix and total acidity (TA) values of berry were significant ($p<0.05$), differences in pH and must yield were insignificant in grafted and nongrafted combinations. Nutrient contents of leaf and root samples were different compared to grafted and nongrafted combinations. Since our study area is infested with phylloxera (*Daktulosphaira vitifoliae* Fitch) and rootstock use is obligatory, the order of preference for grapevine rootstocks was 41 B, Rupestris du Lot and 110 R, considering yield and quality characteristics.

Keywords: Grapevine; Grafting; Mineral Nutrition; Own Rooted; Quality; Rootstock Choice; Yield

1. Introduction

It is known that in grapevine rootstocks change the mineral element profile of the scion type (Cordeau, 1998; Bavaresco et al 2003). The development of cultivars Vitis vinifera under cultivation is profoundly influenced by rootstocks selected from among different Vitis species such as *V. berlandieri, V. riparia* and V. rupestris. Grapevine rootstocks are chosen by growers to provide resistance to various pathogens, tolerance to abiotic stresses such as drought, frost, lime, high salinity, and Fe deficiency, in addition to resistance to Phylloxera (Arrigo & Arnold, 2007; Corso & Bonghi, 2014). Many reports have shown that V. vinifera scion cultivars grafted onto rootstocks affect growth vigor, yield, berry development, grape quality, and wine quality (Gawel et al 2000; Ollat et al 2001; Reynolds & Wardle, 2001; Main et al 2002; Tandonnet et al 2010;

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Gregory et al 2013). The same grape variety exhibits a different phenotype compared to the rootstock, as root characteristics (for example, water and mineral uptake and transport) strongly influence shoot and berry development at both physiological (eg stomatal conductivity affecting photosynthetic activity) and metabolic (accumulation of secondary metabolites) levels (Serra et al 2014). For this reason, it is tried to determine the most suitable scion/rootstock combinations for viticulture in a particular area (Koundouras et al 2006; Meggio et al 2014).

There are many reports of mineral uptake and distribution in vines. Varieties grafted onto rootstocks have a significant effect on mineral nutrition and they differ in their effects on the nutrient levels of the scion (Ibacache & Sierra, 2009). In addition, different results are seen when different varieties are grafted to the same rootstock. On the other hand, the effects of rootstocks on mineral absorption are different, and the differences are due to differences between rootstocks in terms of nutrient absorption and transport. Moreover, the nutrient composition of leaves depends on the scion and rootstock (Garcia et al 2001). Little is known about the mechanisms by which vine rootstocks absorb minerals (Ibacache & Sierra, 2009). Csikász-Krizsics & Diófási (2008) reported that mineral absorption depends on many factors such as root system, soil, and above-ground parts. However, differences in mineral absorption may be due to rootstock genotype (Rizk-Alla et al 2011), environmental fac-tors, and differences in compatibility in scion-rootstock combination, giving different absorption capacity or propensity for some specific minerals. Correct rootstock selection can help reduce nutrient delivery by using rootstocks with high absorption (Ibacache & Sierra, 2009).

This study was carried out to examine the change in yield, quality and mineral nutrition of Ekşi Kara grape variety grafted onto three different rootstocks (Lot, 41 B, 110 R) and on their own roots.

2. Materials and Methods

The study was carried out in Central Anatolia, Konya province, Hadim district, Yağcı Village, Aladağ Valley at 37°2'15"N 32°34'53"E, at an altitude of 1060 m above sea level, approximately 20 years old, in double-armed cordon training, in a short-pruned producer's vineyard. The trial vineyard was established in 2002 with Ekşi Kara saplings grafted on their own roots and on 3 different rootstocks. Soil analysis was carried out in the samples taken from 0-30 and 30-60 cm depths in the vineyard. At 0-30 and 30-60 cm depth, P was determined as 43.3 kg da^{-1} and 17.5 kg da^{-1}, K 61.7 kg da^{-1} and 39.8 kg da^{-1}, Mn 6.3 ppm 4.55 ppm, Zn 0.85 ppm and 0.43 ppm, B 0.4 ppm and 0.24 ppm, respectively. Gök Üzüm was used for each combination as a pollinator variety in the vineyard. Since the region is in the upper valley of the Göksu river, it is partially under the influence of the Mediterranean climate.

Numerical data obtained from the study were subjected to variance analysis by Duncan multiple comparison test and dose and duration applications in SPSS 22.0 statistical program (SPSS Inc, Chicago, IL, USA) Tukey test in JMP 13.0 statistical program (Yue et al 2017).

3. Results

The effects of rootstocks in different combinations were evaluated by analyzing their effects on yield during harvest, product quality in the samples taken, and nutritional element analyzes in root and leaf samples taken during the fall period.

3.1. Cluster quality parameters

The effect of different rootstocks on the cluster characteristics of Ekşi Kara grape variety deter-mined during the harvest period was significant. While the most clusters (45.00 ± 3.00 pieces), the heaviest cluster (379.17 ± 31.04 g), the longest cluster (18.13 ± 0.15 cm), the widest cluster (12.69 ± 0.45 cm) were obtained from Ekşi Kara on its own roots, The fewest clusters (23.00 ± 7.55 pieces), the lightest cluster (100.56 ± 6.74 g), the shortest cluster (15.90 ± 0.18 cm), the narrowest cluster (7.86 ± 0.26 cm) were obtained from Ekşi Kara grafted onto 110 R rootstock (Fig. 1).

McCraw et al (2005) found that Freedom rootstock significantly increased the average cluster weight compared to its rooted Chardonnay vine. Similarly, the total grape yield per decare was significantly lower than the own-rooted Chardonnay vines compared to other rootstocks. Satisha et al (2010), in their study in which they grafted the cv. Thompson Seedless onto five different rootstocks with its own-rooted, they obtained the highest number of clusters from vines grafted onto 110 R rootstocks, and the lowest cluster weight from their own-rooted vines.

Miele & Rizzon (2017), examined the rootstock effects of Cabernet Sauvignon (CS) vine on yield components, the variables were significantly affect-ed by the year and rootstock, the CS/Solferino com-bination affected the year, and the yield per vine was significantly higher than the CS/Rupestris du Lot combination. They also determined that the number of clusters per vine and cluster weight were affected by rootstock.

Although it is understood that rootstocks affect cluster weight and size in previous studies, the results obtained according to their own roots and rootstocks were inconsistent with each other. Vine rootstocks and grape varieties grafted on them are affected by environmental, edaphic, climatic, biotic, and abiotic stress factors at different levels and form dissimilar cluster compositions. Although the location where we study is infested with phylloxera, vineyards can be established on its own roots, albeit limited, but this situation is not sustainable. Since the use of rootstocks is mandatory for new vineyard plantations in the region, 41 B was the most prominent rootstock in terms of cluster weight and size, followed by Lot and 110 R.

3.2. Quality parameters

The differences between the berry weight, berry width, berry length and berry volume values deter-mined during the harvest period were significant ($p<0.05$) (Figure 2). The highest value of berry weight (3.64 ± 0.37 g) was obtained from own-rooted vines, while the lowest value was determined in Ekşi Kara grafted onto 110 R (2.40 ± 0.11 g) rootstock.

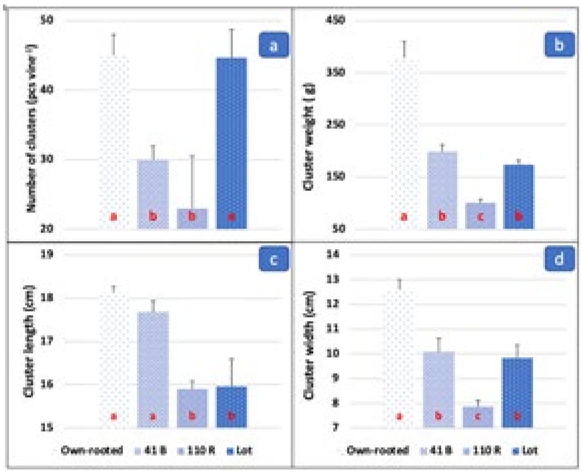

Figure 1. Number of clusters (a), cluster weight (b), cluster length (c), cluster width (d)

The highest value of berry width was determined in vines on Lot rootstock (18.66 ± 0.36 mm), while the lowest values were in vines grafted onto 110 R (13.88 ± 0.29 mm) rootstock. In terms of berry length, vines on their own roots (20.21 ± 0.30 mm) provided the highest value, while the lowest value was recorded in cv. Ekşi Kara grafted onto Lot (15.62 ± 0.19 mm) rootstock.

The highest value of berry volume (3.48 ± 0.16 ml) was obtained from own-rooted vines, the lowest berry volume (2.10 ± 0.09 ml) was determined in Ekşi Kara berries grafted on 110 R rootstock.

Satisha et al (2010), grafted cv. Thompson Seedless onto 5 different rootstocks (Dog Ridge, 110 R, 1103 P, 99 R and Lot) with their own root. In this study, seed diameter was affected by rootstock use, the lowest diameter was determined in those grafted onto Lot rootstock, while the highest diameter value was obtained in vines grafted onto Dog Ridge rootstock. Contrary to our study, the researchers determined the lowest berry diameter values in vines grafted on Lot rootstock.

Walker et al (2010), reported that two different cultivars (Chardonnay & Merbein) grafted onto eight rootstocks generally yielded higher berry weight, cluster weight, cluster per shoot and total yield compared to vines on their own roots.

While previous studies have shown that rootstocks affect berry weight and size, inconsistent results have been reported between own-rooted grape varieties and those grafted onto rootstocks. In our study, the most prominent grape rootstock was 41 B, followed by Lot and 110 R, in the ranking made by considering berry weight and size.

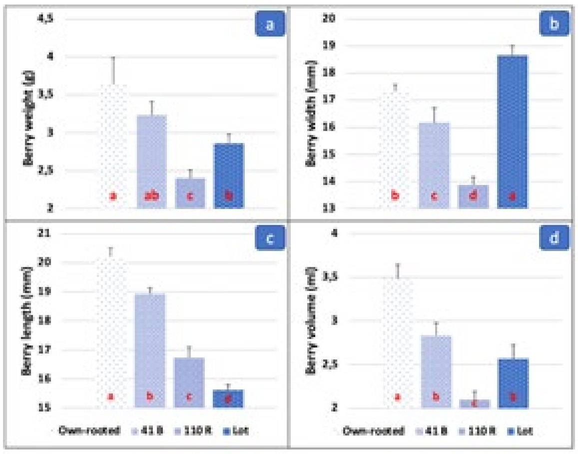

Figure 2. Berry weight (a), berry width (b), berry length (c), berry volume (d)

3.3. Effects on must composition

While the differences between °Brix and TA (%) values determined in berry samples taken during the harvest period were significant ($p<0.05$), the effects of rootstocks on pH and must yield were limited (Figure 3). In terms of °Brix, the highest value (20.97 ± 0.87) was obtained from vines on Lot rootstock, while the lowest value (17.77 ± 0.23) was found in vines on their own roots.

Climate is a factor influencing °Brix in grapevines. Grapes harvested from Chardonel grafted onto 110 R rootstock in warm climates had a higher °Brix than product harvested from vines onto Nor-ton and 5 BB rootstocks. When this study was re-peated in California, rootstocks produced a similar °Brix value (Main et al 2002).

In our study, TA was recorded highest from vines on their own roots (5.03 ± 0.14) and lowest from vines on 110 R (3.98 ± 0.15) rootstock. Chou & Li (2014) studied °Brix and TA variation by grafting cv. Kyoho on their own roots, 5 C and 1202 C rootstocks. Own-rooted Kyoho and Kyoho/5 C combinations provided a satisfactory and equal amount of °Brix on both pruning cycles.

Contrary to our results, in this study, the lowest TA was detected in self-rooted vines among the three stem/rootstock combinations. In other words, the acid decrease occurred the fastest in Ekşi Kara on its own roots. The wort yield differences by rootstock were insignificant and the ranking was Lot (63.40 ± 1.59), own-rooted (62.35 ± 0.79), 41 B (60.96 ± 3.75), and 110 R (59.60 ± 2.48).

In our study, the effects of rootstocks on must pH values were insignificant. Cirami et al (1994) examined cv. Shiraz on five different rootstocks and their own roots, they found that the pH values of the cv. Shiraz berries on their own roots were lower than those of the berries grafted on the rootstocks.

Studies with different grape varieties have shown that rootstocks affect the must composition as well as vegetative and reproductive development (Ruhl et al 1988; Reynolds & Wardle, 2001; Heuvel et al 2004). Jin et al (2016), compared the berry quality changes caused by rootstocks in Summer Black grape variety with their rooted vines and determined that cluster weights and berry structure were changed at different rates by rootstocks.

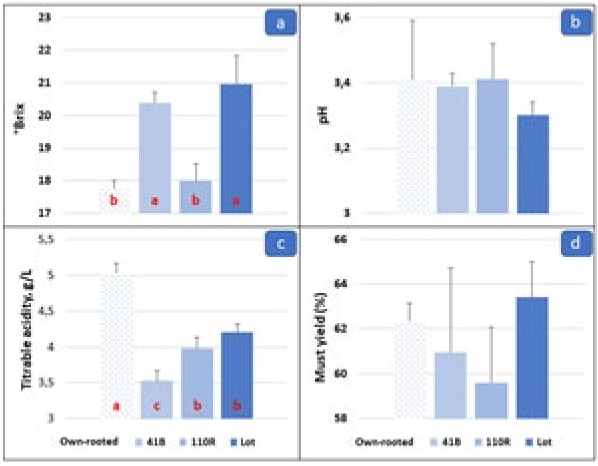

Figure 3. °Brix (a), pH (b), TA (c), must yield (d)

3.4. Effects on yield

According to the rootstocks, significant ($p<0.05$) differences were determined between the cluster number and cluster weight values during the harvest period and the calculated yield per vine and per decare (Fig 1).

While the highest value (17.05 ± 1.62 kg) in terms of yield per vine was obtained from the vines on their own roots, the lowest value was determined in 110 R (2.30 ± 0.68 kg) rootstock. The highest value in terms of yield per decare was obtained from the vines on their own roots (28415.28 ± 2698.35 kg), while the lowest value was 110 R (3825.04 ± 1129.27 kg) rootstock.

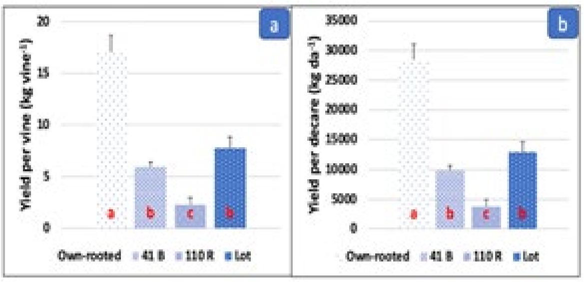

Figure 4. Yield per vine (a), yield per decare (b)

Vine rootstocks and grape varieties grafted on them are affected at different levels by environmental, edaphic, climatic, biotic, and abiotic stress factors, and different yield values occur. Ferree et al (1996), determined that Cabernet Franc and White Riesling varieties on their own roots were more productive than those grafted on different rootstocks. Walker et al (2010), determined that two different cultivars (Chardonnay and Merbein) grafted on eight rootstocks generally produced higher seed weight, cluster weight, cluster per shoot, and overall yield compared to vines on their own roots.

In another study, when cv. Thompson Seedless grafted onto five different rootstocks and own root-ed, the rootstocks caused a significant difference in terms of four-year yield average, while the highest yield was obtained from vines grafted onto 110 R rootstock, and the lowest yield was obtained from vines grafted onto Lot rootstock and own-rooted vines (Satisha et al 2010).

In our study, own-rooted vines gave the highest value in terms of yield per vine and decare, while vine rootstocks were listed as Lot, 41 B and 110 R.

3.5. K, P, B, Mn, Zn contents in roots and leaves

Macro and micro element contents were different according to analyzed plant parts and rootstocks (Figure 5). In the analysis of root samples, macro elements K (6076.92 ± 375 ppm) and P (2132.87 ± 179.50 ppm) were highest in vines on their own roots.

The lowest K (3064.27 ± 137.41 ppm) and P (951.07 ± 66.87 ppm) levels were determined in the vines grafted onto 110 R rootstock. In leaf samples, unlike the roots, the highest K content (9123.08 ± 484.26 ppm) was determined in the vines onto 110 R rootstock, while the lowest value (7165.40 ± 144.60 ppm) was detected in the vines on their own roots.

In the K content analysis of variance of root samples, vines on their own roots were in the first group with the highest content, while the K content of leaf samples had lower values.

Ibacache et al (2016), showed that rootstocks can have a significant impact on grapevine nutrition. When grafting Flame Seedless, Thompson Seedless, Superior Seedless and Red Globe grape varieties on ten different rootstocks (Freedom, Harmony, St. George, Salt Creek, SO4, 1613 C, 1103 P, 99 R, 110 R, 140 Ru, own-rooted) Flame Seedless, Red Globe and Thompson Seedless cultivars grafted onto Harmony and 1613 C rootstocks had 60% higher K values than those on their own roots.

Ahmad et al (2018), examined the effects on petiole macro element content by grafting three grape cultivars (Halawani, Baladi and Bayadi) onto 41 B, 140 Ru, SO4 and Fercal rootstocks, they determined that SO4 rootstock increased the petiole K level. Petiole K content was highest in Baladi/SO4 and Halawani/SO4 combinations (2.4% and 2.3% in 2010; 2.213% and 1.91% in 2011, respectively).

In leaf samples, P content was highest in vines on 41 B rootstock (2286.82 ± 91.22 ppm), and lowest in vines on 110 R rootstock (1878.55 ± 41.00 ppm).

In previous studies, it was determined that P up-take varied according to rootstocks (Grant & Matthews, 1996a; Grant & Matthews, 1996b). Chenin Blanc vines grafted on Freedom rootstock had little difference in root morphology compared to vines grafted on St. George, but when there was sufficient P in the soil (> 8 mg/kg dry soil according to the Bray 1 method), it took up more and provided transport (Grant & Matthews, 1996a). In another study, Freedom and 110 R rootstocks provided acceptable vine growth in low and adequate soil P conditions, while vines on St George rootstock were inhibited to grow at low soil P content (Grant & Matthews, 1996b).

Ibacache & Sierra (2009), Flame Seedless, Thompson Seedless, Superior Seedless and Red Globe grape varieties were grown on ten rootstocks (Freedom, Harmony, St. George, Salt Creek, SO4, 1613 C, 1103 P, 99 R, 110 R, 140 Ru, own-rooted) detected significant differences in nutrient content levels in all cultivars relative to rootstocks. They determined significantly higher P in the petioles of the vines grafted on Salt Creek rootstock than in the vines on their own roots. They determined at least 60% higher K levels in Flame Seedless, Red Globe and Thompson Seedless cultivars on Harmony and 1613 C rootstocks than on their own rootstocks.

B, Zn and Mn contents of microelements were different in root samples compared to rootstocks. While the highest values of B (27.18 ± 0.53 ppm) and Mn (293.62 ± 15.58 ppm) contents in root samples were in the vines on their own roots, the lowest values were in Lot (B 23.11 ± 1.68 ppm- Mn 60.01 ± 7.87 ppm) rootstock.

The B response of plants differs not only by plant species, soil type and environmental conditions, but its excess, deficiency and availability of other plant nutrients can also affect uptake. Some researchers have determined that source B can affect the accumulation and utilization of other essential nutrients as a regulator or inhibitor (Alvarez-Tinaut et al 1979; Tinaut et al 1979). Excessive B concentration can interfere with metabolic processes, thereby affecting the absorption of other nutrients by plants (Corey & Schulte, 1973). On the other hand, B deficiency can also lower levels of phytonutrients (Carpena Artes & Carpena Ruız, 1987). A deficiency of B impairs cell division in the meristematic region, resulting in amorphous flower and fruit development and significant inhibition of root elongation, while adequate B enhances beneficial root growth (Gupta & Solanki, 2013). There is limited information on the effect of rootstocks on B uptake in vines. Leaves of the cv. Sugraone grafted onto Ramsey and Ruggeri rootstocks and irrigated at two salinity levels did not show any significant difference in B accumulation (Yermiyahu et al 2007).

Ekbic et al (2018), applied four different boric acid (H3BO3) doses (control, 0.1%, 0.2%, 0.3%) to cv. Isabella (*Vitis labrusca* L.) in two different periods (one week before and after full bloom). In Isabella, they recommended 0.3% boric acid application for high quantity and quality yield, since foliar B applications affect yield, quality, and foliar nutrition, and stimulate plant growth and development.

Tangolar & Ergenoglu (1989), determined the highest Mn content in Grüner Veltliner samples on 41 B rootstock by examining the leaf nutrient change by grafting the Grüner Veltliner grape variety to 10 different rootstocks.

The highest Zn content in root samples (4979.62 ± 843.54 ppm) was determined in vines grafted on Lot rootstock, while the lowest value (189.53 ± 14.01 ppm) was determined in vines on their own roots, unlike other microelements.

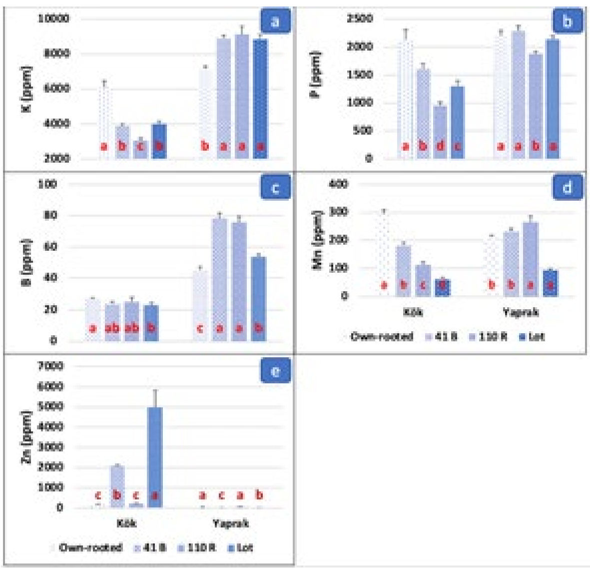

Figure 5. Root and leaf K, P, B, Mn, Zn contents

The highest values in leaf samples were deter-mined as B (78.45 ± 3.36 ppm) on vines on 41 B rootstock, Zn (58.03 ± 4.79 ppm) and Mn (264.47 ± 22.68 ppm) on vines on 110 R rootstock. The lowest values were determined as B (44.99 ± 2.17 ppm) on the vines on their own roots, Zn (14.10 ± 1.33 ppm) on the vines on 41 B rootstock, and Mn (92.67 ± 5.99 ppm) on the vines on Lot rootstock, respectively.

Kidman et al (2014), micronutrients such as Zn, B, and Mo, and macronutrient calcium are necessary for the pollination and fertilization process in vines. Rootstocks of Syrah cultivar affected feeding and reproductive performance. 1103 P showed significantly higher B level, less seedless fruit and a lower millerandage index. On the other hand, they determined Zn deficiency in grapevines grafted on 110 R and 140 Ru. They emphasized that the studies could produce site-specific responses but cannot produce precise predictions for other soil-climatic conditions or cultivars.

Zn is as important as nitrogen, potassium, etc. in terms of metabolic functions in plants. For this reason, it is of great importance for plants to find Zn in the environment where they grow, to take them in sufficient levels and to use them in their metabolism as necessary to obtain qualified and abundant products (Taban & Koç, 2006)

4. Discussion

In general, the vine rootstocks used in this study are the most widely used as they are well suited to the location of the experiment, but the correct root-stock selection depends on various aspects such as soil characteristics, climatic conditions, grape varieties and even clones and production purposes. In our study, the highest values in terms of cluster and berry quality parameters were determined in the vines on their own roots, while the lowest values were determined in the vines grafted onto 110 R rootstock.

Although some literature shows that self-rooted vines give better results in terms of berry-cluster quality characteristics, rootstock use is mandatory considering environmental, edaphic, climatic, biotic, and abiotic stress factors. In this case, since it gave the best results in terms of berry-cluster quality parameters, the rootstock that stood out locally was determined as 41 B, followed by Rupestris du Lot and 110 R.

Yield per decare and yield per vine are similar, and the highest productivity values were obtained from the vines on their own roots. In grafted vines, the highest yield per vine and decare was obtained from vines on Lot rootstock, followed by 41 B and 110 R rootstocks.

Harvested grape quality was affected by rootstocks. When quality parameters and yield were evaluated together in cv. Ekşi Kara, the highest values were obtained from vines on their own roots, while the highest values were obtained from Ekşi Kara/41B grafted combinations, followed by Ekşi Kara/Rupestris du Lot and Ekşi Kara/110 R.

According to the data we obtained from root and leaf samples, Ekşi Kara vines on 110 R rootstock gave the best results in terms of plant nutrient content, followed by 41 B and Lot rootstocks.

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Conflicts of Interest: Authors declare that they have no competing interests.

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