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Effects of different rootstocks on the growth and yield characteristics of Papazkarası (*Vitis vinifera* L.)

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Abstract

Rootstocks, which are becoming increasingly important in viticulture, influence the growth, yield, and grape quality of the grafted variety. Therefore, understanding the resistance characteristics of rootstocks to phylloxera, nematodes, environmental conditions, and abiotic and biotic stresses is crucial. Selecting a rootstock that is appropriate for the region where the vineyard will be established optimizes grape quality. The aim of this research is to determine the performance of the cv. Papazkarası on different rootstocks. For this purpose, an experiment was established at Irem Çamlica Viticulture and Winery Co. vineyard in Kırklareli province. Ten-year-old Papazkarası vines grafted onto 1103P, 110R, and 420A rootstocks were used as plant material. To determine the growth of the vines, parameters such as shoot elongation rate (cm/week), shoot length changings (cm), pruning wood weight (PW) (kg/vine), vigor (g), puissance, number of buds per square meter (number), balanced pruning buds number (number/vine), vegetative growth (VG), Ravaz Index (RI), Partridge Index (PI), and yield (kg/vine) were examined. Additionally, to determine cluster characteristics, cluster width and length (cm), weight (g), and the volume of gappy and spaceless clusters (cm^3) were measured. The results of the research indicated that the 1103P rootstock had the lowest yield, puissance, RI, PI, and VG values; moderate values for PW, vigor, number of shoots, number of berries per cluster, and cluster length; and the highest values for cluster weight, the volume of gappy and spaceless clusters. The 110R rootstock was found to be more balanced compared to other rootstocks, with the highest values for vigor, RI, and PI; average values for yield, puissance, and VG; and the lowest values for PW, number of shoots, number of berries per cluster, cluster length, weight, and the volume of gappy and spaceless clusters. The 420A rootstock had the highest values for yield, PW, VG, number of shoots, number of berries per cluster, and cluster width and length; average values for RI, PI, cluster weight, and the volume of gappy and spaceless clusters; and the lowest value for one-year-old cane weight. In conclusion, based on the characteristics outlined, a selection can be made from these rootstocks according to cultivation purposes, but other rootstocks should also be investigated.

Keywords: Autochthonous, Thrace, Cluster, Partridge Index, Ravaz Index

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INTRODUCTION

Rootstocks influence the vigor, yield, and quality of the grafted grapevine cultivar. They also facilitate the adaptation of the grafted variety to environmental conditions (Zombardo et al., 2020; Ferrandino et al., 2023; Bahar et al., 2024). However, viticulture is also affected by climate change, making rootstock selection crucial for adaptation (Atak, 2024). Rootstocks are becoming increasingly important in vineyard management and can alter the yield and response of the cultivar to edaphic stresses (Rodriguez et al., 1998; Stevens et al., 2008). It has been indicated that certain rootstock-cultivar combinations affect the source-sink relationship, vegetative expression, vigor, yield, and the balance of vegetative-generative growth (Mattii et al., 2005; Sampaio and Vasconcelos, 2005).

On the other hand, for success in viticulture, it is necessary to graft cultivars onto rootstocks resistant to abiotic and biotic stresses (El-Gendy, 2013; Opazo et al., 2020; Tedesco et al., 2020; Fayek et al., 2022). Tandonnet et al. (2005) reported that rootstocks can be used not only to impart resistance to certain biotic stresses but also to control vegetative expression and yield, thereby optimizing grape composition. These stresses include resistance to drought, salinity, Fe-deficiency, and diseases (Cookson et al., 2014; Corso and Bonghi, 2014; Mariani and Ferrante, 2017; Abdel-Mohsen and Rashedy, 2023). In recent years, the demand for stress-resistant cultivars has grown, leading to a significant increase in breeding studies on rootstocks tolerant to biotic and abiotic conditions (Atak, 2022). The breeding of new grape rootstocks that use water more efficiently is a very important strategy against global climate change (Atak et al., 2023). Rootstocks, mandated in 19^{th}-century Europe due to phylloxera, are now required globally, partly due to nematodes (Whiting, 2012; Bona et al., 2007).

Yazar et al. (2023) noted that grafting different varieties onto the same rootstock yields varying results, attributing this to environmental factors and the compatibility between the scion and rootstock. An example of this is the study by Rodriguez et al. (1998), which found that the pruning wood weight of the cv. Cabernet Sauvignon grafted onto the 140Ru rootstock was equal to the pruning wood weight obtained from 1103P, SO4, and Harmony rootstocks.

The relationship between the rootstock-scion combination affects vegetative growth and yield in vines (Santarosa et al., 2015). Additionally, it should be noted that rootstocks have a significant impact on the mineral nutrition of the grafted variety, affecting the nutrient levels of the scion differently (Ibacache and Sierra, 2009). Csikász-Krizsics and Diófási (2008) reported that the absorption of minerals from the soil depends on the root system of the rootstock, the soil, and the above-ground organs of the vine. This distribution may be influenced by the genotype of the rootstock (Rizk-Alla et al., 2011). Rootstocks, likely due to their role in root density, influence numerous scion traits such as water and gas exchange, canopy growth, and yield. Rootstocks can increase the vigor of the grafted variety, potentially leading to lower phenolic maturity in grapes (Koundouras et al., 2009). Different rootstocks are reported to alter the growth, development, fruit quality, and stress resistance of the variety (Ulaş et al., 2014).

Papazkarası, an autochthonous cultivar grown primarily in the Trakya region, particularly in Edirne-Kırcasalih (Korkutal et al., 2019), and very late ripening (Çelik, 2006). Ozen et al. (1993) studied the development of Papazkarası grapevines grafted onto seven different rootstocks under the ecological conditions of Edirne in the Trakya region from 1988 to 1993. They found that the 140Ru rootstock had the most balanced values in terms of bome degree (9.54), yield (624 kg/da), and grape juice (51.3%). Karaca Sanyürek et al. (2018) reported that cv's Papazkarası and Ulaş Siyahı had the highest total phenolic compound content when they examined the content of some local wine grapes. Bozan et al. (2008) also found that the total phenolic content of Papazkarası seeds was higher than other grape varieties. Gülcü et al. (2018) stated that, in terms of suitability for grape juice, the cv's Öküzgözü and Papazkarası had the highest grape juice. Additionally, the traditional fermented drink hardaliye, which contains high levels of antioxidants, is produced from this cultivar (Faikoğlu, 2014).

The aim of this research is to determine the performance of the cv. Papazkarası on different rootstocks. Within this scope, morphological characteristics (yield, shoot elongation rate, shoot length changings, pruning wood weight, vigor, puissance, number of buds per m^2, balanced pruning buds number, number of clusters, number of shoots, vegetative growth, Ravaz Index, Partridge Index) and cluster characteristics (cluster width-length, weight, the volume of gappy and spaceless clusters) will be evaluated.

MATERIALS AND METHODS

Plant Material

The trial was conducted in a vineyard located in Poyralı Village, Kırklareli, at an altitude of 304 m. Ten-year-old cv. Papazkarası scions were used as plant material. The scions were grafted onto 1103P, 110R, and 420A vine rootstocks. The vineyard had a planting density of 2x1 m, and the vines were trained to a bilateral cordon with Royat pruning system.

Papazkarası cultivar is a wine and table grape variety grown in Uzunköprü (Kırcasalih, Yeniköy, Aslıhan) in Trakya and in Central Anatolia (Anonymous, 1990). It has been noted that Kırklareli and Üsküp are the best terroirs for this variety (Lacombe et al., 2012). It produces medium-sized, dense clusters. Another characteristic is its very late ripening. The wines with medium-low tannins, high acidity, and aromatic profiles.

1103P rootstock (Berlandieri Resseguier No.2 x Rupestris du Lot) was hybridized by Paulsen in 1892. This rootstock delays the ripening of the grafted variety and promotes the formation of numerous lateral shoots. When grafted with late-ripening varieties in northern regions, its shoots may be damaged by early autumn frosts. It is tolerant to about 16-17% active lime in the soil (Whiting, 2003; Plantgrape, 2024).

110R rootstock (Berlandieri Resseguier No.2 x Rupestris 110 Richter) is highly tolerant to the root form of phylloxera. It has moderate resistance to limestone but can withstand about 17% active lime in the soil. It is highly drought-resistant but not well-suited to excessively moist soils (Whiting, 2003; Plantgrape, 2024).

420A rootstock (Berlandieri x Riparia 420A Millardet et de Grasset) is a weak-growing rootstock. It is highly resistant to both limestone and phylloxera. It accelerates the ripening of the grafted variety. It does not thrive in dry soils; it prefers well-drained, moist, and fertile soils. Rooting of its cuttings is quite difficult (Whiting, 2003; Plantgrape, 2024).

Methods

The experiment was established in accordance with a Randomized Complete Block Design with 4 replications in Poyralı Village. A total of 144 vines were used, with 12 vines per replication, and the vines at the beginning and end of each row were excluded from the trial. For cluster measurements, 120 clusters (10 clusters per vine in each replication) were selected. In total, 1440 clusters were harvested from the vineyard and evaluated.

Statistical Analysis

The criteria examined during the development phase and the analysis results of the grape clusters harvested were evaluated using the MSTAT-C statistical software package. Differences among rootstocks were determined using the Least Significance Difference test.

Climate and Phenological Development Stage

Climate data between 2014 and 2021 were obtained from the Kırklareli Directorate of Meteorology (KDM, 2022). Phenological development stages were recorded throughout the vegetation period.

Determination the Vigor and Yield

Shoot growth rate (cm/week) was measured weekly after marking one shoot per vine (Bahar et al., 2008). Shoot length changings (cm) was determined by measuring the difference between the last and previous measurements of the same shoot (Bahar and Öner, 2016). Pruning wood weight (PW) (kg/vine) was determined by weighing the main and lateral branches obtained from pruning 12 vines per plot (Carbonneau et al., 2007). Vigor (g) was calculated by dividing the total PW values by the total number of shoots (Carbonneau et al., 1998; Smart et al., 1990). Puissance was calculated using the following formula (Carbonneau et al., 1998):

$$\text{Puissance} = \left[\left(\text{PW}\left(\frac{\text{kg}}{\text{vine}}\right)\text{x } 0{,}5\right) + \left(\text{Yield}\left(\frac{\text{kg}}{\text{vine}}\right)\text{x } 0{,}2\right)\right]$$

The number of buds per square meter (number) was determined by assuming 5 to 6 buds/m² on a vine. The area per vine (APV) was calculated, and the formula APV x (5 and 6 buds/m²) was used to determine the number of buds per unit area of soil. Calculations were made separately for 5 and 6 buds/m², and the required number of buds per vine was determined from the resulting values. Balanced pruning bud number (BPBN) was calculated based on the assumption of 20 buds for the first 0.5 kg PW, 10 buds for the next 0.5 kg PW (for wine grape varieties), and 10 buds for each remaining 0.5 kg PW (per vine) (Shaulis, 1950; Skinkis and Vance, 2013). Vegetative growth (VG) was given in the following formula:

$$\text{VG} = \text{PW}\left(\frac{\text{kg}}{\text{vine}}\right) + \text{Yield}\left(\frac{\text{kg}}{\text{vine}}\right)$$

A balance between vegetative and generative growth should be established in the vineyard. To determine this, the Ravaz Index (RI) was calculated as the ratio of yield to PW. A result of 5-10 indicates balanced vegetative-generative growth; <5 indicates more vegetative growth, and >10 indicates higher yield (Ravaz, 1903; Smart et al., 1990). The Partridge Index (PI) was determined by comparing yield (kg/vine) to the previous year's PW (kg/vine), reflecting the idea that the previous year's pruning wood weight affects the yield and quality of the following year (Partridge, 1925). Yield (kg/vine) was calculated by weights of all harvested clusters.

To determine cluster characteristics, one cluster was selected from each vine, and measurements were performed on a total of 144 clusters (OIV, 2009). Cluster width (cm) and length (cm) were measured using a ruler. Cluster weight (g) was obtained by dividing the yield per vine by the number of clusters. Cluster spaceless volume (cm³) was determined by submerging the cluster in a water-filled glass container and measuring the displaced water volume; gappy volume (cm³) was determined similarly after packaging the cluster in plastic (Bahar et al., 2023).

RESULTS AND DISCUSSION

Climate Data and Phenological Development Stages

The Kırklareli region, classified as semi-arid and low-moisture, exhibits a Black Sea climate in its northern parts and a continental climate in its interior. Over the long term (2014-2020), the annual average temperature recorded was 14.26°C, decreasing to 13.88°C in 2021. These two temperature values were found to be quite close to each other. The long-term average rainfall was 634.69 mm, whereas in 2021, it was determined to be 913.20 mm (KDM, 2022). However, it was observed that while the long-term average precipitation during the vegetation period (April-October) was 323.81 mm, in 2021, the precipitation during the vegetation period was recorded at 341.10 mm. In summary, it was noted that the rainfall in 2021 occurred largely outside the vegetation period.

When examining the phenological development stages of the cv. Papazkarası, it was observed that EL23 occurred on June 26 for the 1103P and 110R rootstocks, and on June 22 for the 420A rootstock. Veraison was determined to take place on September 10 for the 1103P rootstock, and on September 5 for the 110R and 420A rootstocks. Harvest was recorded on October 15 for the 1103P and 420A rootstocks. However, due to the maturity of grafted vines with the 110R rootstock occurring on October 10, to better assess uniformity and the impact of the rootstock on maturity, it was conducted on October 10 (Figure 1). Similar conclusions were drawn in this study as Keller et al. (2012), indicating that rootstocks did not significantly affect vine phenology. Likewise, the study corroborates the findings of Harbertson and Keller (2012), showing a minor influence of rootstocks on harvest dates.

Candar et al. (2022) recorded that cv. Papazkarası vine saplings grown under Tekirdağ conditions in pots on their own roots reached EL04 stage on April 2, 2019 and April 18, 2020, EL17-19 stage on June 24, 2019 and July 16, 2020, and EL33-35 stage on July 24, 2019 and July 17, 2020. According to the research, the EL04 stage varied depending on the rootstocks but generally occurred in the first week of May. It was observed that cv. Papazkarası grown on its own roots and in pots started bud break within the month of April. These findings contradict the researcher's own findings. However, it is believed that controlled conditions such as pots may have caused this difference. Flowering initiation was found to occur in the second week of June, which is consistent with the researcher's findings. The dates of veraison observed in the second half of July conflicted with the veraison dates obtained from the study, with the difference potentially originating from variations in climate between Kırklareli and Tekirdağ, vine age, applied cultural practices, and other factors. It should also be noted that Candar et al. (2022) grew the cv. Papazkarası on its own roots, which is an important aspect to consider.

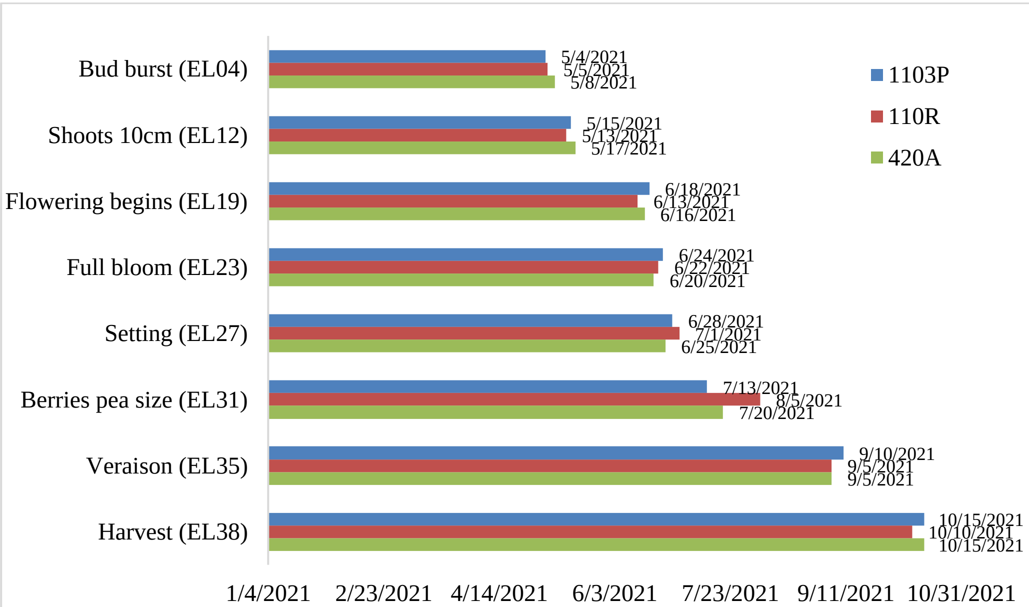

Figure 1. Phenological development stages of cv. Papazkarası grafted onto different rootstocks

Soil Analysis

Analysis was conducted using samples taken at depths of 0-30 cm and 30-60 cm. In the soil where Papazkarası vines grafted onto 1103P rootstock were located, the percentages of sand were 46.6% and 48.4%, silt 29.7% and 31.9%, clay 23.5% and 19.6%, respectively, for depths of 0-30 cm and 30-60 cm. For the 110R rootstock at both depths, the sand percentages were 40.1% and 38.1%, silt 41.4% and 45.3%, clay 18.3% and 16.5%. The soil percentages for the 420A rootstock were 36.5% and 35.1% sand, 46.8% and 44.4% silt, and 16.5% and 20.4% clay for depths of 0-30 cm and 30-60 cm, respectively. The higher sand content in the area where 1103P vines are planted suggests faster heating and cooling of the soil, leading to more rapid vine development, which is considered normal. An increase in silt values was observed from 1103P to 110R and 420A. The clay content in the soil ranged from a minimum of 16.5% to a maximum of 23.5% at both depths.

Growth and Yield

The rootstocks onto which cv. Papazkarası has been grafted have statistically influenced the number of shoots per vine. The highest number of shoots per vine, 14, was recorded in vines grafted onto the 420A rootstock. The lowest number of shoots, 11, was observed in vines grafted onto the 110R rootstock. The number of shoots per vine for the 1103P rootstock was determined to be 13, placing it between the other two rootstocks (Table 1). In cv. Malbec grafted onto the 1103P rootstock, it was found that there were 22 shoots per vine. This value was significantly higher compared to the findings of the research, indicating that the variety grafted onto the rootstock influenced this value.

Table 1. Effects of rootstocks on yield and vine development.

Criteria	Rootstocks			
	1103P	110R	420A	Rootstock Main Effect
Number of shoots per vine	13,00 ab	11,00 b	14,00 a	12,60
Pruning wood weight (PW)	0,440 ab	0,404 b	0,477 a	0,440
Vigor	37,00	38,00	36,00	37,00
Puissance	0,527 b	0,595 ab	0,645 a	0,589
Balanced pruning bud number (BPBN) (0.5 g)	17,60	16,16	19,08	17,60
Vegetative growth (VG)	2,00 b	2,37 a	2,51 a	2,29
Ravaz Index (RI)	3,81 b	5,00 a	4,52 ab	4,40
Partridge Index (PI)	4,04 b	5,68 a	5,15 ab	4,90
Yield	1,57 b	1,96 ab	2,03 a	1,85

Number of shoot $LSD_{0,01}$=0,2103; PW $LSD_{0,01}$=0,2103; Vigor $LSD_{0,05}$=0,2802; VG $LSD_{0,05}$=1,1773; RI $LSD_{0,01}$=0,2802; PI $LSD_{0,05}$=1,1773; Yield $LSD_{0,01}$=1,3950

The seven-week shoot growth rate values are given in Figure 2. Starting from the first week, the shoot growth rate in the 1103P rootstock has noticeably stood out and has extended more each day compared to the other rootstocks. The shoot growth rates of 110R and 420A rootstocks followed a similar trend (Figure 2).

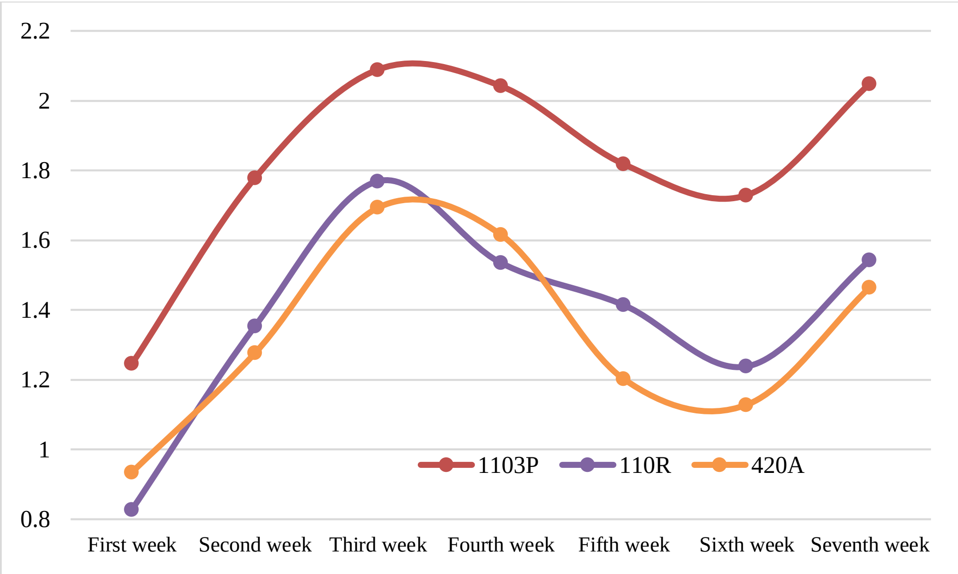

Figure 2. Shoot growth rate changings per week

The variation in shoot lengths of cv. Papazkarası according to the rootstocks has been examined based on phenological development stages (Lorenz et al., 1995). It was observed that the shoot length of the 1103P rootstock was longer than the others at every phenological stage. During the last measurement period at berry set (EL 27), the shoot length of the 1103P rootstock was 95.6 cm. On the same day, the shoot lengths of the other two rootstocks were recorded as 73.6 cm for 110R and 71.3 cm for 420A (Figure 3).

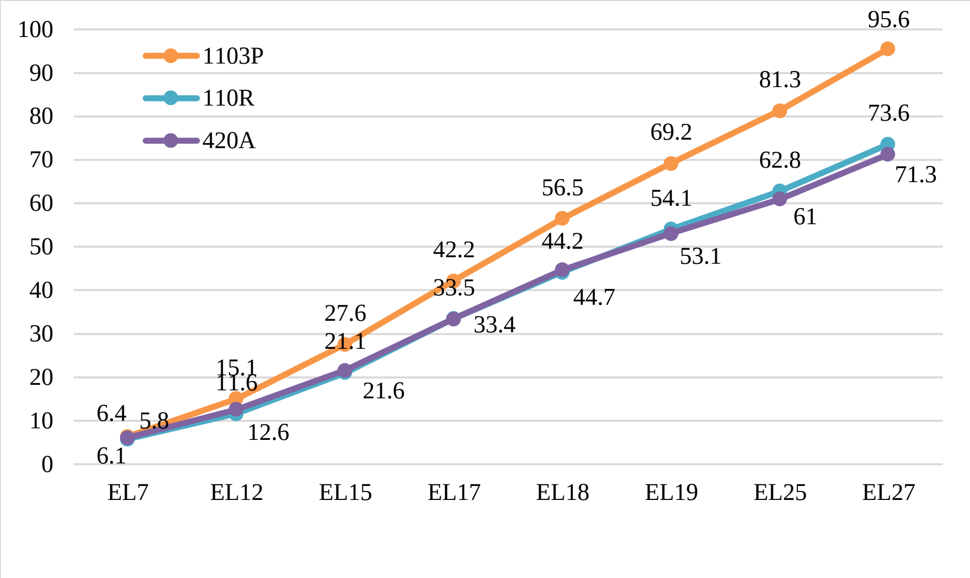

Figure 3. Variation of shoot length according to phenological development stages

The statistical analysis determined that the pruning wood weight (PW) of cv. Papazkarası varied according to the rootstocks (Table 1). The highest PW was obtained from the 420A rootstock (0.447 kg/vine), and the lowest was from the 1103P rootstock (0.440 kg/vine). It was noted that the 1103P rootstock (0.440 kg/vine) fell between these two. Contrary to the findings indicating an average PW of 1.39 kg/vine for the cv. Malbec grafted on the 1103P rootstock by Di Filippo and Vila (2011), significantly different results were obtained, which were attributed to the grafted variety.

The influence of different rootstocks on the vigor of cv. Papazkarası was found to be insignificant. However, numerical values were lined up as 38 g (110R), 37 g (1103P), and 36 g (420A) (Table 1). According to Smart et al. (1990), the evaluation based on the formula “vigor = pruning wood weight / shoot number” indicated that values between 20-40 g are among the thresholds for “moderate vigor”.

The effect of rootstocks on the vigor of the cv. Papazkarası was found to be statistically significant at the $LSD_{0.05}$ level (Table 1). In terms of vigor, the highest value was recorded for the 420A rootstock (0.645 g). Following this, the 110R rootstock showed a 0.595 g. The lowest vigor was obtained from the 1103P rootstock (0.527 g). Since vine vigor between 0.5-1 g is considered “ideal” for wine grape varieties (Carbonneau et al., 1998), it was determined that all rootstocks exhibited “ideal” vigor. According to the research findings, the vigor of the 110R rootstock states between the values of the other two rootstocks. Similarly, Satisha et al. (2010) found the Thompson Seedless/110R graft combination to perform well in terms of moderate vigor, increased berry set rates, and consistently higher yields. Consistent with this research, Keller et al. (2012) also noted a tendency for the 1103P rootstock to reduce shoot vigor.

In general, the number of buds per square meter on vines is reported to be 5 to 6 buds (Carbonneau et al., 1998). In the trial vines, the area allocated per vine was calculated as 2 m². Based on this area, it was determined that there should be 10 buds/m² (2 x 5 = 10 buds/m²) or 12 buds/m² (2 x 6 = 12 buds/m²). Therefore, the number of buds per unit area was established as 10-12 buds/m². Considering the trial vines are trained in the bilateral cordon Royat System, with 3 shoots on each side (left and right) forming a total of 6 shoots per vine, the target of 10-12 buds/m² was achieved.

Shaulis (1950) explained that balanced pruning involves leaving 20 buds for the first 0.5 kg of PW, followed by 10 more buds for each additional 0.5 kg (for wine grape varieties). Using this method, leaving 20 buds per vine (Table 1) was found to be appropriate (Skinkis and Vance, 2013).

It has been determined statistically that different rootstocks affect the vegetative growth (VG) of cv. Papazkarası. The highest VG was obtained from the 420A rootstock (2.51); the lowest was from the 1103P rootstock (2.00), with the value between them from the 110R rootstock (2.37) (Table 1).

Ravaz Index (RI) varied significantly depending on the rootstocks onto which cv. Papazkarası was grafted (Table 1). The highest RI value of 5.00 was recorded from the 110R rootstock. This value, being at the lower limit, indicates “a balanced vegetative-generative development”. However, the RI values of 3.81 for 1103P rootstock and 4.52 for 420A rootstock are significant in showing a tendency towards “more vegetative growth” (Ravaz, 1903; Smart et al., 1990).

Analyzing the Partridge Index (PI) for rootstock effects, the 110R rootstock achieved the highest value of 5.68 PI, while the 1103P rootstock showed the lowest value of 4.04 PI. In the case of the 110R rootstock, the previous year’s vegetative growth had a promoting effect on this year’s yield, whereas for the 1103P rootstock, it reduced yield. The 420A rootstock (5.15 PI) among these two values (Table 1).

In terms of yield, statistically significant differences have been observed. The highest yield of 2.03 kg/vine was obtained from the 420A rootstock, while the lowest yield of 1.57 kg/vine from the 1103P rootstock. The value between these two was recorded from the 110R rootstock at 1.96 kg/vine (Table 1). This finding aligns with Ulaş et al. (2014), who also indicated that rootstocks significantly influence yield. Di Filippo and Vila (2011) found that the Malbec/1103P grafting combination increased yield to 2.78 kg/vine. Similarly, Rodriguez et al. (1998) reported that among different rootstocks used for Cabernet Sauvignon, the 1103P achieved the highest yield of 2.7 kg/vine. However, in this study, the 1103P rootstock yielded the lowest, contrasting with these findings. This discrepancy suggests that there may be an interaction between the scion and rootstock, as noted by Tandonnet et al. (2005). However, Striegler et al. (2002) observed minimal differences in yield when grafting Cabernet Franc onto four different rootstocks, which contradicts these research findings. It is hypothesized that this variation could be due to the genetic makeup of the variety, cultural practices applied, and soil characteristics.

Cluster Characteristics

It has been statistically determined that the number of clusters per shoot varies depending on the rootstock (Table 2). Accordingly, the rootstock with the highest number of clusters per shoot is 110R (10 cluster/shoot). The rootstock with the lowest number of clusters per shoot is 1103P (7 cluster/shoot). The 420A has an intermediate value with 8 cluster/shoot. Satisha et al. (2010) found contradictory results regarding the minimum number of clusters per shoot from the Thompson Seedless/110R grafting combination. This discrepancy is thought to come from environmental, soil, climate, and stress factors. Striegler et al. (2002) indicated that the Cabernet Franc/110R combination produced more clusters per shoot compared to the Freedom rootstock, although the clusters from the Freedom rootstock were heavier. Similar findings were obtained in this study, where the 110R rootstock produced more clusters per shoot, while the 1103P and 420A rootstocks resulted in heavier clusters.

Table 2. Some cluster characteristics of Papazkarası grape variety grafted onto different rootstocks.

Criteria	Rootstocks		
	1103P	110R	420A
Number of clusters per shoot (cluster/shoot)	7,00 b	10,00 a	8,00 ab
Berry number of cluster (number)	108,83 ab	93,52 b	120,31 a
Cluster weight (g)	278,13 a	201,07 b	263,46 ab
The volume of spaceless clusters (cm^3)	230,94 a	163,01 b	206,21 a
The volume of gappy clusters (cm^3)	380,83 a	270,29 b	346,04 a

Number of clusters per shoot $LSD_{0,01}$ =1,3950; Berry number of cluster $LSD_{0,05}$=18,93728; Cluster weight $LSD_{0,01}$=62,6115; The volume of spaceless clusters $LSD_{0,05}$=39,78276; The volume of gappy clusters $LSD_{0,05=}$ 74,41092

Berry number of cluster was found to be significantly influenced by rootstocks at the $LSD_{0.05}$ level. The rootstock with the highest number of berries per cluster was 420A (120.31 number), while the lowest number was recorded with the 110R rootstock (93.52 number). The 1103P rootstock fell between these two values (108.83 number) (Table 2). Di Filippo and Vila (2011) reported a berry number per cluster of 50.28 for the Malbec/1103P grafting combination, which contrasts with the findings of this research. This discrepancy may underscore the genetic influence of the variety on berry number within clusters. Yazar et al. (2023) obtained consistent results when grafting the Ekşi Kara grape variety onto the 110R rootstock, showing the lowest cluster berry number.

The rootstock effect on cluster width and length was found to be statistically insignificant. Cluster width values ranked highest to lowest as 420A, 110R, and 1103P. The highest width value (14.48 cm) was attributed to the 420A rootstock. Cluster length values followed the order of 420A, 1103P, and 110R (Figure 4). Yazar et al. (2023), grafting the cv. Ekşi Kara onto the 110R rootstock, reported obtaining the lowest cluster width and length values, conflicting with the cluster length findings in this study, although the cluster width findings are consistent.

Figure 4. Cluster width and length according to the rootstocks

The effect of rootstocks on cluster weight is statistically significant. The rootstock with the highest cluster weight is 1103P, with a value of 278.13 g. The lowest cluster weight, 201.07 g, is obtained from the 110R rootstock. The 420A rootstock cluster weight between these values with a of 263.46 g (Table 2). For the Malbec/1103P graft combination, Di Filippo and Vila (2011) reported a 92.63 g, which differs significantly from the findings of this study, indicating the prominent role of grape variety characteristics. However, the higher cluster weight obtained from this variety grafted onto other rootstocks supports the findings of this research. Additionally, consistent with findings from Yazar et al. (2023), the Ekşi Kara/110R graft combination yielded the lowest values. Moreover, the research findings align with Todorov (1970)'s observation of a positive relationship between cluster weight and shoot growth. Clusters from the 1103P rootstock, which also exhibited the highest shoot elongation rate and length, were found to be heavier compared to those from other rootstocks.

The volume of spaceless clusters shows a statistically significant rootstock effect. Rootstocks 1103P and 420A (230.94 cm^3 and 206.21 cm^3, respectively) are in the same significance group. The 110R rootstock, with a value of 163.01 cm^3, is in another significance group (Table 2).

The volume of gappy clusters also varied significantly by rootstocks; the highest value was obtained from rootstocks 1103P and 420A (380.83 cm^3 and 346.04 cm^3, respectively). The 110R rootstock, with a value of 270.29 cm^3, is in another group (Table 2).

CONCLUSION

Based on the research, rootstocks were evaluated, with 1103P generally showing moderate to lower results in morphological characteristics. It had the lowest values for yield, vigor, RI, PI, and VG but exhibited the highest for cluster weight and volume. The 110R rootstock provided balanced results, excelling in vigor, RI, and PI, while showing lower values for cluster characteristics. The 420A rootstock, known as the weakest, showed the highest values for yield, PW, VG, and shoot number but smaller berry size, indicating strong cluster development but smaller berries. The 420A showed high morphological development and balanced cluster development.

In conclusion, the rootstocks 1103P, 110R, and 420A used in this study are the most commonly used for the Papazkarası variety in the Thrace Region due to their suitability. However, for successful rootstock selection, the soil structure and environmental conditions of the area should be examined more carefully and in detail. For the cv. Papazkarası grown in this region, if balanced cluster development and relatively high yield (1015 kg/da) are desired, the 420A rootstock is recommended. If average development and yield (980 kg/da) are preferred, the 110R rootstock is suitable. For rapid shoot development and low yield (785 kg/da), the 1103P rootstock should be chosen. However, similar studies should be conducted with rootstocks other than these, and the results should be observed.

Compliance with Ethical Standards

Peer-review

Externally peer-reviewed.

Conflict of Interests

The authors have no conflicts of interest to declare.

Author contribution

Concept -E.B.; Data Collection and/or Processing-S.E., E.B.; Analysis and/or Interpretation- E.B., İ.K., S.E.; Literature Search-İ.K., S.E.; Writing Manuscript-İ.K.; Critical Review-E.B.

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