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EGE UNIVERSITY
Graduate School of Applied and Natural Science



EFFECT OF DIFFERENT ROOTSTOCKS ON FRUIT QUALITY AND PLANT NUTRIENT CONTENT OF ALMOND CVS. ‘FERRAGNES’ AND ‘FERRADUEL’

MSc Thesis

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Horticulture Department

İzmir

2022

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ALMOND CVS. ‘FERRAGNES’ AND ‘FERRADUEL’**

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İzmir
2022

**EGE UNIVERSITY GRADUATE SCHOOL OF NATURAL
AND APPLIED SCIENCES**

ETHICAL DECLARATION

I hereby declare that this thesis study entitled as “**Effect of Different Rootstocks on Fruit Quality and Plant Nutrient Content of Almond Cvs. ‘Ferragnes’ and ‘Ferraduel’**” represents my own work which has been done after registration for the degree of MSc at Ege University, and has not been previously included in a thesis or dissertation submitted to this or any other institution for a degree, diploma or other qualifications. I also declare that all the information in this document has been obtained and presented in accordance with Ege University academic rules and regulations as well as ethical conduct. Lastly, I declare that, as required by these rules and conduct, I have fully cited and referenced all material and results, which are not original to this work.

07 / 01 / 2022

Dorukhan ÇANTAL

ÖZET**FARKLI ANAÇLARIN FERRAGNES VE FERRADUEL BADEM
ÇEŞİTLERİNDE MEYVE KALİTESİ VE BİTKİ BESİN İÇERİĞİNE
ETKİLERİ**

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Ocak 2022, 56 Sayfa

Badem uygun anaç, uygun çeşit kombinasyonları ile kaliteli meyvelerden oluşmuş verimli ağaçlarıyla yetiştiriciliğinin yapılması gereken ılıman iklim meyve türüdür. Meyve ağacı anaçları üzerine aşıllı olan çeşitlerin meyve pomolojik özelliklerine, verim, meyve kalitesi ve bitki besin element içeriklerine etki etmektedir. Bu çalışmada Garnem, GF 677 ve badem çöğürü üzerine aşıllı olan ‘Ferragnes’ ve ‘Ferraduel’ çeşitlerinin pomolojik özellikleri (kabuklu ve iç badem ağırlıkları, boyları, genişlik ve kalınlıkları, iç randımanı), verim, antioksidan kapasiteleri, toplam fenol içerikleri, yağ asitleri ve bitki besin maddesi içerikleri iki yıl boyunca belirlenmiştir. Yapraklarda yapılan Azot (N) analizlerinde ‘Ferraduel’ çeşidinin Garnem ve GF-677 anaçlarından alınan örneklerde sırasıyla %2,29 ve %2,44 oranında önemli derecede yüksek bulunmuştur. Fosfor (P) içerikleri ise GF-677 anacına aşılansmış ‘Ferraduel’ badem çeşidinde %0,35 oranında en yüksek tespit edilmiştir. Potasyum (K) analizlerinde birinci yıl Ferraduel aşıllı Garnem ağaçlarından alınan meyve örneklerinde %0,67 oranında yüksek değer gözlenmiştir. Magnezyum (Mg) seviyeleri meyve örneklerinde farklı çıkmazken, ‘Ferraduel’ aşıllı garnem ağaçlarından alınan yapraklarda %1,27 oranında en yüksek belirlenmiştir. Badem örneklerinde başlıca yağ asitleri olarak palmitik, palmitoleik, stearik, oleik, linoleik ve linolenik asit tespit edilmiştir Farklı anaçlarda yetiştirilen bademlerin antioksidan aktiviteleri 4,80-9,50 μ mol TE/g FW, toplam fenol içerikleri 56.21-133,14 mg GAE/100 g FW arasında değişmiştir. Çöğür anaçlarının

antioksidan ve fenol içerikleri GF-677 anacına ve Garnem anacına göre yüksek bulunmuştur. Çöğür anaç ve Garnem anacında yetiştirilen her iki badem çeşidinin meyve boyutları Garnem anacındaki bademlere göre daha yüksek bulunmuştur. İç doldurma oranı her iki yılda ortalama Çöğür/Ferraduel 22,14%, Garnem/Ferraduel 23,21%, GF-677/Ferraduel 23.59%; ortalama Çöğür/Ferragnes 33.82%, Garnem/Ferragnes 32.54%, GF-677/Ferragnes 34.12% olarak bulunmuştur. Badem ağırlıkları ve boyutları çöğür anaçta fazla olsada, diğer iki klon anacın iç doldurma oranları yüksek bulunmuştur. ‘Ferraduel’ çeşidine ait verim değerleri ağaç başına ortalama çöğür anaçta 6.38 kg, Garnem anacında 14.8 kg, GF-677 anacında 12.36 kg; ‘Ferragnes’ çeşidinde ise çöğür anaçta 5.9 kg, Garnem anacında 16.34 kg, GF-677 anacında 13.29 kg olarak belirlenmiştir. Çöğür anaç verim değerleri her iki çeşitte de oldukça düşük bulunmuştur. Her ne kadar Garnem anacının verim değerleri yüksek olsa da GF-677 anacının kabuklu ve iç badem ağırlıkları, meyve boyutları Garnem anacına göre daha yüksek olduğu saptanmıştır. GF-677 anacının da verim değerlerinin yüksek olduğu göz önüne alındığında Ferragnes ve Ferraduel badem yetiştiriciliği için GF-677 anacının uygun olduğu belirlenmiştir.

Anahtar kelimeler: Badem, Anaç, Meyve kalitesi, Verim, Antioksidan Aktivitesi, Toplam fenol içeriği, Yağ asitleri, Bitki besin elementleri.

ABSTRACT**EFFECT OF DIFFERENT ROOTSTOCKS ON FRUIT QUALITY
AND PLANT NUTRIENT CONTENT OF ALMOND CVS.
‘FERRAGNES’ AND ‘FERRADUEL’**

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January 2022, 56 pages

Almond is a temperate climate fruit that should be grown with appropriate rootstocks, convenient variety combinations, and reproductive trees with quality fruits. Fruit tree rootstocks affect the fruit pomological characteristics, yield, fruit quality, and plant nutrient content of the grafted varieties. In this study, the pomological properties (The weight of the shelled fruits and kernels, length, width, thickness, kernel yield), yield, antioxidant capacities, total phenol contents, fatty acids, and nutrient contents of the 'Ferragnes' and 'Ferraduel' varieties, which are grafted on Garnem, GF 677 and Seedling rootstock were determined for two years. Nitrogen (N) analyses carried out on the leaves were found to be significantly higher in samples taken from Garnem and GF-677 rootstocks grafted with the 'Ferraduel' variety with the ratio of 2.29% and 2.44%, respectively. Phosphorus (P) content was found to be the highest at 0.35% in the 'Ferraduel' almond variety grafted on GF-677 rootstock. In Potassium (K) analyses, a high value of 0.67% was observed in fruit samples taken from 'Ferraduel' grafted on Garnem trees in the first year. Magnesium (Mg) levels did not differ in fruit samples, while was the highest in leaves taken from 'Ferraduel' grafted on Garnem trees with a rate of 1.27%. Palmitic, palmitoleic, stearic, oleic, linoleic, and linolenic acid were the main fatty acids in almond samples. Antioxidant activities of almonds grown in different rootstocks ranged between 4.80-9.50 μ mol TE/g FW, and total phenol content between 56.21-133.14 mg GAE/100 g FW. The antioxidant and phenol

content of Seedling rootstocks were found to be high compared to GF-677 rootstock and Garnem rootstock. The fruit size of both almond varieties grown on Seedling rootstock and Garnem rootstock were found to be higher than those of Garnem rootstock. The kernel yield average for both years was found to be 22.14% in Seedling/Ferraduel, 23.21% in Garnem/Ferraduel, 23.59% in GF-677/Ferraduel, 33.82% in Seedling/Ferragnes, 32.57% in Garnem/Ferragnes, and 34.12% GF-677/Ferragnes. Although the almond weights and lengths were higher in the Seedling rootstock, the kernel yields of the other two clone rootstocks were found to be high. The yield values of 'Ferraduel' cultivar were determined as 6.38 kg per tree on average, 14.8 kg on Garnem rootstock, 12.36 kg on GF-677 rootstock; In the Ferragnes variety, it was determined as 5.9 kg in the Seedling rootstock, 16.34 kg in the Garnem rootstock, and 13.29 kg in the GF-677 rootstock. Considering that the yield values of GF-677 rootstock were high, GF-677 rootstock was determined to be suitable for 'Ferragnes' and 'Ferraduel' almond cultivation.

Keywords: Almond, Rootstock, Fruit quality, Yield, Antioxidant activity, Total phenol content, Fatty acid, Plant nutrients.

PREFACE

This research was conducted in order to increase the supply sufficiency of the entire demand for almonds. During this project, we gained a deep awareness of the almond production deficit.

In Turkey, almond production has been present for long years. Despite increasing total production of almonds in recent years, the production of almonds is not at the desired level yet. By Turkish Statistical Institute (TUIK) data, almond production has increased a hundred percent of ten years ago. Especially the economic value of almonds is quite effective to increase interest the almond cultivation. Besides the economic value of almonds, there are many benefits to human health, thus almond is one of the most demanded edible nuts by the people.

The rootstock is one of the most important factors influencing the profitability of fruit growing. It offers flexible and often the cheapest method of tree vigor control. Different studies conducted on *Prunus spp.* have demonstrated that rootstock influences the performance of the grafted scion cultivar. The root system of the rootstock enables the uptake of water and nutrients from the soil. In addition, rootstocks are very effective in root anchorage and indirectly effective in their growth rate.

It also has been demonstrated that rootstock influences the fruit quality of the scion cultivar. The use of rootstocks causes an effect on the mineral nutrition of the grafted variety. As well as influencing mineral absorption, almond rootstocks can affect fruit yield and quality.

The three more important components in the organoleptic quality of fruit are aroma, sugar content, and acidity, which are all related to many physicochemical properties of fruits, and these properties are highly influenced by rootstocks. Some studies conducted in peach (Byrne et al., 1991) have investigated the relationships between some fruit quality traits with agronomical parameters, such as the relationships between trunk cross-sectional area (TCSA) and fruit weight and between TCSA and soluble solids content (SSC).

Almond trees can be seen scattered throughout the country in Turkey, as naturally grown plants, or planted in lands that are considered non-arable. Most often, almond trees are used on property lines throughout Anatolia. The traditional location of cultivated orchards for almonds is the Datca Peninsula in the southern part of the Aegean coast. The total area of almond orchards has been increased over the years. Starting in the early 2010s, the city of Adiyaman in the Southeastern Anatolia Region has become the center of almond production in Turkey due to its suitable climate and soil. There are also almond orchards in the province of Manisa, where the climate is suitable for cultivating almond trees. New orchards have been established to meet the demand. In Manisa, the conventional Seedling rootstocks are used as almond rootstocks in orchards. GF677 and Garnem are used as clonal rootstocks. The most widely grown almond varieties are Ferragnes, Ferraduel, Teksas, Nonpareil, Penta, and Lauren. For this region, the effect of these rootstocks on plant nutrient uptake and biochemical composition of the fruit is not well known. In addition, there is no clear data on vegetative growth and phenolic observations, and fruit quality parameters. The objective of this study is to investigate the effect of different almond rootstocks on vegetative growth, yield, nutrient uptake, fruit quality of the ‘Ferragnes’ and ‘Ferraduel’ almond trees.

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07 / 01 / 2022

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1. INTRODUCTION

Almond (*Prunus amygdalus L.*), which is one of the hard-shelled fruit (nut) species, is included in the genus *Prunus*, there are about 40 almond species in the subgenus *Amygdalus*. Twenty of these species are grown in our country (Soylu, 2003). Almond is an underproduced variety among nuts in Türkiye (159,187 tons), and its production comes after the production of hazelnuts (665,000 tons), pistachios (296,376 tons), walnuts (286,706 tons). Thirty-three percent of almond cultivation is carried out mainly in the Mediterranean Region, followed by the Southeastern Anatolia Region with 25% and the Aegean Region with 23%, respectively (TUIK, 2020).

Our production of almonds could not meet our own domestic consumption, and we imported 44,767 tons in 2019 (TUIK, 2020). It is of great importance that the country's needs should be met with domestic production instead of imports and that the surplus product of the needs is directed to export and provides input to the national economy.

Until recent years, the fact that some of the almond production in Türkiye is obtained from scattered gardens, the idea that almonds can be grown without irrigation, the failure to fulfill the conditions of grown in these scattered gardens, the inability to make the right rootstocks and variety selections suitable for ecological conditions have caused the inadequate production of our closed gardens. We have almond trees that are not uniform examples in scattered gardens, which are grown from seed, have a low yield, and are influenced by spring frosts, which significantly reduce our production. In order to eliminate these reasons, it is necessary to increase the number of closed gardens where standard maintenance operations are carried out with the correct varieties on ecological clone rootstocks that are suitable for ecology.

Almond is a kind of temperate climate fruit that should be grown with its fertile trees, suitable rootstocks, and suitable variety combinations with quality fruits. Cultivation of varieties grafted on fruit tree rootstocks affects fruit pomological characteristics, yield, fruit quality, and plant nutrient content. These

parameters are of great importance for the sustainable cultivation of almonds. Therefore, it is very important to establish a garden with the selection of varieties grafted on rootstocks suitable for ecology.

Its high economic value and the amount of nutrients contained in it cause an increased interest in almonds. In recent years, the planting of almond orchards in the province of Manisa in the Aegean Region has been increasing. Thanks to the Demirköprü dam located in the Köprübaşı district of Manisa province, its climate is mild and it is a suitable place for almond production. In this region, due to the favorable ecology, the almond orchard establishment is increasing rapidly. Almond seedling rootstocks, GF-677, and Garnem rootstocks are used in almond orchards in the region. The most widely grown almond varieties in the region are 'Ferragnes', 'Ferraduel', 'Teksas', 'Nonpareil' and 'Lauren'.

For this region, the effects of grafting on rootstocks on plant nutrient content intake are unknown. In addition, there is no clear data on the effect of these varieties grafted on these rootstocks on fruit quality parameters. Therefore, this study aimed to investigate the plant nutrient intake, fruit quality parameters, and yield parameters of "Ferragnes" and "Ferraduel" almond varieties grafted on seedling, GF-677, and Garnem rootstocks used in almond cultivation in the region.

2. PREVIOUS STUDIES

2.1 The Effects of Rootstocks On Some Quality Characteristics Of Fruit Trees

The rootstock is one of the most important factors that affect the profitability of the production. Rootstock usage provides the cheapest control on tree vigor while providing a wide range of usage areas. Breeding programs are in progress on rootstock varieties all around the world. Many studies are being held on hard-shelled fruit rootstocks including almonds (Moreno and Webster, 2004). *Prunus spp.* is one of the studied rootstocks, the effects of this rootstock usage on some properties of grafted variety, such as water interactions, gas exchange through leaves, mineral intake, tree height, flowering time, amount of fruit buds, production efficiency, and tree vigor (Albás et al., 2004; Beckman et al., 1992; Layne, 1994; Zarrouk et al, 2005). The root system of the plants is required to perform absorbing the soil nutrients and water into plant, many studies showed that rootstock usage directly affects the nutrient and water intake and proportionally fruit quality parameters (Albás et al., 2004; Caruso et al., 1996; Giorgi et al., 2005; Loreti and Massai, 2002; Remorini et al., 2008).

The mineral substance content of fruits is also associated with fruit ripening and the quality of fruits (Giorgi et al., 2005; Hofman et al., 2002; Smith and Clark, 1989). Rootstocks play a crucial role in fruit quality (Hofman et al., 2002). The fact that fruit rootstocks are not dwarf, semi-dwarf, or full dwarf affects the characteristics of fruit varieties. Because there is less competition between the vegetative parts of the tree and fruit in dwarf rootstocks, they can send more nutrients to fruits (Faust, 1989). However, it was determined in a different study that the leaves of plums grafted on dwarf rootstock Pixy contain less calcium (Boyhan et al., 1995).

Rootstock usage may also fulfill the gap of adapting trees to saline soil and expand the agricultural area in production (Karimi and Hasanpour 2014). In a study, researchers conducted experiments on the Mazzetto almond variety grafted on GF677 and Garnem rootstocks in terms of soil salinity. Mazzetto/Garnem plants

showed the highest development by maintaining the stoma conductivity and minimizing the photosynthetic production loss. Mazzetto/Garnem plants showed higher amounts of gs, carotenoid/Chlorophyll, anthocyanin/chlorophyll, and nutritional elements (K^+ , Ca^{+2}), proline, water-soluble organic matters, and lower amount of Na^+ with lower leaf water content in comparison with the Mazzetto/GF677 plants. In conclusion, Garnem rootstock showed higher resistance against high salinity (Zrig et al., 2016).

A study indicated that Ferragnes almond variety grafted on GF305 and GF-677 rootstocks caused no difference in terms of flowering and harvest times. On the other hand, the production efficiency was affected by rootstock usage (Barbara et al., 1994). However, another study reported that the same rootstock combination did affect the flowering and harvest times in the Red Haven peach variety (Okie et al., 1992). The effect of rootstocks on fruit quality characteristics may be different on the same varieties.

Rootstock choice has a different effect on each grafted variety used in combination. A comprehensive study showed that in the Flavorcrest peach variety, four different rootstocks (Ishtara, Mr. S 2/5, GF-677, Barrier1) altered the fruit quality parameters, harvest time, and nutritions (vitamin C, phenols, carotenoids, total antioxidant capacity). Some positive effects in terms of the above-mentioned variables were observed in Mr. S 2/5 and Barrier 1 rootstocks. Especially Mr. S 2/5 rootstock showed the highest amounts of antioxidants and beneficial phytochemicals even though the fruits were relatively harder (Remorini et al., 2008).

Rootstock choice affects the yield per tree, water-soluble organic matter, fruit hardness, and fruit sugar components. A large-scale study was conducted on cherry variety “Lapins” (*Prunus avium* L.) grafted onto 12 different rootstocks (F 12/1, Maxma 14, Piku 1, Edabriz, Gisela 5, Gisela 195/20, Weiroot 13, Weiroot 158, and Weiroot 72), so their pomological and biochemical characteristics were investigated. There were no significant differences between rootstocks in average yield per tree, except for Piku 1 (19.7 kg) with significantly the highest and Gisela 5 with significantly the lowest average yields per tree (7.7 kg). Significant

differences in the measured parameters were ascertained among fruits of Lapins grafted onto different rootstocks. Lapins grafted onto Weiroot 72 and Edabriz resulted in high soluble solids content and fruit firmness. The lowest fruit firmness was measured on the fruits from Weiroot 13, F 12/1, Gisela 195/20, and Maxma 14 trees (Usenik et al., 2010).

Making a choice in the direction of Redhaven and Royal Glory peach rootstocks will directly affect the fruit mass, sugar content, organic acids, and phenols, which was reported in a study where 7 different rootstocks including GF-677 were used (Orazem et al., 2011).

To be able to obtain good results of fruit quality and productivity, it is essential to select the right rootstock/scion pair. Another study confirmed that different rootstocks ('Flordaguard', 'Barton', 'MP-29', 'P-22', and 'Okinawa') coupled with subtropical variety UFS alters the fruit quality parameters such as fruit size, water-soluble mass, dry matter, phenols and antioxidants (Shahkoomahally et al., 2021).

Rootstocks directly affect vegetative development and fruit size. The effects of rootstocks on fruit quality were investigated by studies in which Rainha Claudia Verde (*Prunus domestica*) plum variety was used in combination with Marianna GF8-1 and Marianna GF10-2 rootstocks. Higher vegetative development was observed in Marianna GF8-1 along with this rootstock, providing bigger fruits with higher calcium levels. Both rootstocks showed similar fruit hardness during the harvest, however, GF10-2 plants resulted in harder fruits during the storage. Moreover, the rootstocks did not affect the water-soluble mass and acidity (Rato et al., 2008).

The rootstock choice affects the levels of antioxidants and phenols in fruits. Another study revealed the effect of rootstocks on parameters such as dry matter, sugar content, fruit firmness, and phenols in the Lapins cherry variety (Usenik et al., 2010). Other studies confirmed that rootstocks change the levels of antioxidants and phenol levels of the grafted variety (Kviklys et al., 2014, Cheng et al., 2017, Ochmiana et al., 2019). Another study in which eleven apple varieties were grafted

on different rootstocks suggested that super-dwarf rootstocks had the highest phenol content while semi-dwarf and dwarf rootstocks had lower phenol content (Kviklys, 2014).

The rootstock factor affects the fruit size, maturation time, antioxidant, and phenol content. A recent study investigated the “Suncrest” peach variety scions grafted onto GF677, Barrier1, Isthara, and Julior rootstocks. The highest vegetation rate was observed in GF677 rootstocks followed by Julior. Production efficiency was the same among rootstocks, and fruit size was observed as the biggest on Isthara rootstock. GF677 rootstock plants also yielded the smallest fruits among all. Some variation was observed in maturation times, and Barrier1 rootstock had the latest maturation. Water-soluble fruit mass was not affected by rootstock choice while Barrier1, Julior had the highest fruit acidity. Julior, GF677, and Ishtara caused the highest levels of antioxidants and phenols, and the lowest levels were observed in Barrier1 plants (Giorgi et al. 2005).

Almonds contain a serious amount of antioxidants such as phenols, flavonoids, phenolic acids, tannins, and vitamin E (Rao et al., 2012). Polyphenols, phenolic acids, flavonoids, and tannins contribute to the antioxidant properties of almonds (Milbury et al., 2006; Garrido et al., 2008). The composition and abundance of these molecules completely depend on the variety (Milbury et al., 2006; Barriera et al., 2008). Almonds contain high amounts of phenolic compounds which protect the fruit's fatty acids against oxidative stress (Maestri et al., 2015). Some of the factors affecting the phenol composition and quantity are harvest time, environmental factors, post-harvest processing, and storage conditions along with variety and harvest year. Studies conducted with Nonpareil, Carmel, Butte, Sonora, Fritz, and Mission almond varieties during 3 consecutive years showed that phenolic compounds quantity varies between the varieties and harvest years of the same variety (Bradley et al., 2010).

Almond is one of the most important agricultural products amongst the hard-kernel fruits (Gradziel et al., 2017). Nutritional values of almonds consist of 50-60% oil, 20-25% protein, and 20% carbohydrates on average, and the compositions vary with the genetic and environmental factors (Romojaro et al., 1988). Almond

kernels contain high amounts of unsaturated oils providing energy, which makes almonds a highly nutritive and very satiating food (Hollis and Mattes, 2007). Almond is also known to have a lowering effect on the cholesterol levels of blood (Sabate et al., 1996). Oil molecules in almonds consist of fatty acids of oleic and linoleic acids, but oleic acid quantity is higher in general (García-López et al., 1996; Forcada et al., 2009). The main fatty acid in almonds is oleic acid, followed by linoleic acid. (Forcada et al 2009). Some of the important quality parameters of almonds are total oil content, percentage of oleic acid, oleic acid-linoleic acid ratio (O/L), and tocopherol ratio in almond seed (Kodad et al., 2006; Kodad and Socias, 2008). Almonds do not contribute to the increase of cholesterol in the blood because of their composition containing monounsaturated fatty acids. The high nutritional value of almonds is explained by their composition of high oil, calorie value, and monounsaturated fatty acids. Oleic acid and linoleic acids are the most important and abundant monounsaturated fatty acids in almonds, and the quality of almonds and almond oil are decided by their composition and quantity. These fatty acids are highly affected by rootstock choice and new agricultural orchards are created by considering these parameters to be able to maximize efficiency and quality (Sabaté and Hook, 1996). Studies conducted on the lipid composition of almonds reported that oleic acids change between 62.9%-77.3%, linoleic acid between 14%-26.8%, palmitic acid between 4.9%-7%, stearic acid around 3.4%, and palmitoleic acid between 0.3%-0.6% (Kodad et al., 2011). The most abundant fatty acid in almonds is oleic acid at the rate of 50-80% followed by other fatty acids mentioned above (Kornsteiner et al., 2006; Lopez-Ortiz et al., 2004). The composition of the fatty acids depends heavily on variety, and comprehensive studies done with 24 almond varieties reported a wide variation of fatty acids in almonds (Bolling et al., 2010).

In 24 almond varieties from various regions of the USA, Australia, and Spain, linoleic acid content ranged between 15.7-29.9%, oleic acid between 58.5-71.3%, palmitic acid between 5.9-7.5% in total oil (Zhu et al., 2015).

A study conducted in Spain with 37 almond varieties reported that the oil content of almonds consisted mainly of monounsaturated fatty acids in the form of oleic acid, polyunsaturated fatty acids in the form of linoleic acid, and low amounts of saturated fatty acids in the form of palmitic acid and stearic acid. The most

abundant fatty acid was found to be oleic acid with a ratio of 66.8%-76.2%. The linoleic acid ratio was found between 15.1% and 24.3%, which is inversely proportional to oleic acid quantity. The ratio of linoleic acid/oleic acid changed between 2.5%-5.2% and this ratio is considered as an indicator of fruit quality in almonds (Kodad et al., 2004).

Another factor affecting the oleic acid and linoleic acid content is the cultivation site and the environmental conditions such as climate. Studies conducted in Turkey, in which different almond varieties were included, reported that the climate and orchard location caused different compositions of fatty acids. Unsaturated oil in the form of palmitic acid was observed between 5.76%-7.86% in Adana city and 5.45%-6.59% in Şanlıurfa city followed by stearic acid between 1.14%-3.04% in Adana city and 1.42%-2.45 in Şanlıurfa city. Unsaturated fatty acids in form of oleic acid changed between 63.01%-75.46% in Adana city and 70.73%-77.78% in Şanlıurfa city as the most abundant fatty acid, followed by linoleic acid around 15.53% in Adana city and between 13.63%-20.57% in Şanlıurfa city (Kafkas et al., 1995).

The composition of nutrients in almonds mostly depends on the genotype, however, orchard location, agricultural practice, harvest year, climate, and inner maturation are important environmental factors affecting the nutrient composition (Yada et al 2011).

One of the effective factors is the rootstock composition and studies reported that rootstocks directly alter the nutrient composition, which has to be taken into account during agricultural production plans (Sabaté ve Hook 1996). A study investigated the rootstock effect on fatty acids of the grafted varieties and concluded that the composition of fatty acids was affected by rootstock choice in Pistachios (Acar et al., 2017).

2.2 Rootstock Effect on Plant Nutrient Composition of Leaves and Kernels

Rootstock choice directly affects the nutrition composition of the grafted plant (Boyhan et al., 1995). The fertilizing sufficiency is decided by evaluating the nutritional values in leaves and fruits. One of the most important factors of nutritional content is the rootstock selection and its compatibility with the environment and corresponding properties. Different studies showed that the nutrition content of leaves and fruits is affected by different rootstocks (Hrotko' et al., 2014; Ochmiana et al., 2019).

Fertilizing practices are among the most important variables that alter plant development, fruit quality, and production efficiency. Fertilization is required to be applied according to the plant's needs. Consecutive years of production alter fruit nutrient content, therefore the fertilization program carries importance and needs to be sustainable. A fertilization program should be scheduled by considering plant needs (Akgül and Uçgun, 2004).

Nutritional contents in the soil are absorbed by plants by their root system, especially fringe roots, so a healthy root system is required for a healthy plant. In this case, fringe root abundance plays an important role in the plant's capacity of absorbing nutrients. Almond varieties contain taproot systems, and this property makes almonds more dependent on optimum soil conditions. For example, intaking the elements of Zn, Cu, Fe, and Mn may become a challenge for almonds in clayed soil conditions (Çelik et al., 2012). The growth conditions of plants directly alter the mineral content of fruits (Drogoudi et al., 2013).

In almond varieties, the most abundant elements are K and P consisting of 70% of total almond elements in kernels. Almond kernels are important sources of Ca, Mg, and Mn, and these elements show a reverse proportion with P and K (Schirra, 1997). The growing conditions affect the mineral content of the varieties (Drogoudi et al., 2013).

Studies conducted on GiSelA 6, *Prunus mahaleb*, *Prunus avium*, and *Prunus fruticosa* rootstocks showed that different rootstocks directly affect the nutrition absorbing capacity of the plants. GiSelA 6 rootstock showed a high intake of N, P, K, Zn, B, and Mn elements, however, lower intake of Ca, Mg, and Cu. *Prunus mahaleb* rootstock on clayey soil had a high absorbance value of N, P, K, Ca, Mg, Fe, and Cu and a low intake of Zn, B, and Mn. *Prunus fruticosa*, seedling, had the lowest intake value of N, P, K, Ca, and Cu while lacking some of the elements severely (Hrotko' et al., 2014).

Another study demonstrated that different rootstocks altered the nutritional values of different apple varieties. The rootstock MM106 showed higher nutrient content than its counterpart M9 rootstock (Kucukyumuk and Erdal 2011).

It was proven in another study that was conducted on almond $\times$ peach hybrid rootstocks ('Adafuel', 'Adarcias', 'GF 677', 'Cadaman', 'Garnem' and 'Felinem') and grafted branches of 'Queen Giant' and 'Tebana' peach [*Prunus persica* (L.) Batsch] in terms of mineral content. Queen Giant variety grafted on Cadaman and GF677 rootstocks showed the highest levels of N, P, K, Ca, Mg, Fe, Mn, Na, and Cu in leaves, and the Adarcias variety showed the lowest values of all elements. According to the results of the analysis carried out on the flowers and leaves of different rootstock variety combinations, the effect of rootstocks on the high content of elements such as P, Fe and Zn was noted. It has been observed in Tebana variety that the content of K and Mn in flowers showed a correlation with chlorophyll content. Adarcias variety has smaller branch width but yields a higher amount of product. Queen Giant variety showed a negative correlation between Ca content and total yield. Moreover, development efficiency and Ca content both in leaves and flowers showed a negative correlation. Flowers of Tebana variety and its total production capacity were directly proportional. In comparison with other rootstocks, Felinem rootstock showed the lowest nutritional content with the Queen Giant variety (Zarraouk et al., 2005).

A study conducted on Kinnow mandarins proved that different rootstocks affect the leaves' N, P, and K content directly (Ahmed et al., 2008).

Different apple varieties were studied and it was observed that N absorption was altered by different rootstock choices (Aguirre et al., 2001).

In research on the leaf nutrient content of peach grafted on five rootstocks; researchers concluded that “Aldrichi”, “Capdeboscq”, “Flordaguard”, “Nemaguard” and “Okinawa” rootstocks did not affect the P and Mn leaf content of “Maciel” peach (Mayer et al., 2015).

Another study on the influence of almond x peach rootstocks on mineral nutrient content indicates that the P concentration is higher in 'Adafuel' and 'GF 677', medium in 'Cadaman' and 'Felinem' and lower in 'Adarcias' and 'Garnem'. In a study that investigated the effect of rootstocks on potassium concentrations, although the highest potassium density of peach varieties grafted on 6 different rootstocks (Adafuel, Cadaman, Garnem, Feline, Adarcias, and GF-677) was detected in Felinem rootstock and the lowest in Adarcias rootstock, no significant difference was observed when the values were examined in statistical analysis (Zarrouk et al., 2005a; 2005b).

'UFSun' peach cultivar grafted on 'Okinawa' and 'Flordaguard' rootstocks was analyzed at the optimum level in terms of Ca, K, and Mg leaf concentration and compared to other rootstocks (Shahkoomahally et al., 2020).

The study indicated that the copper content of rootstocks grafted on pistachio cultivar was significantly affected by the rootstock factor (Tavallali and Rahemid. 2008).

Apple cultivar 'BC-2 FUJI' was grafted onto three different rootstocks. It was revealed that the leaves of the Bud.9 rootstock plant have higher manganese (Mn) but lower potassium (K) concentrations than other rootstocks (Fallahi et al., 2001).

3. MATERIAL AND METHODS

3.1 Geographical Properties of the Experimental Area

This study was conducted in 2019-2020 between Karyağdı, Tokmaklı, and Borlu locations. The almond orchard is located in Köprübaşı town (38°45'K; 28°21'D), Manisa city, Aegean region.

3.2 Climatic Conditions of the Experimental Area

The experimental area has a Mediterranean-continental climate where the maximum and minimum temperatures reach up to 41 °C during summer and -11 °C during winter. The average rainfall is 744 mm/year (Table 3.1).

Table 3.1. Average meteorological data in the experimental area from 2019 to 2020

Measurement Period (2019- 2020)													
MANISA	January	February	March	April	May	June	July	August	September	October	November	December	Annual
Avarage Temperature (°C)	6.6	7.9	10.5	15.1	20.3	25.2	27.9	27.6	23.3	17.8	12.1	8.1	16.9
Avarage Highest Temperature (°C)	10.8	12.7	16.2	21.4	27.1	32.1	34.9	34.9	30.7	24.4	17.5	12.3	22.9
Avarage Lowest Temperature (°C)	3.0	3.7	5.3	8.9	13.3	17.5	20.4	20.3	16.1	11.8	7.5	4.4	11.0
Avarage Sunshine Duration (hour)	2.8	3.7	5.1	6.1	8.2	10.2	10.8	10.3	8.6	6.2	3.9	2.3	6.5
Avarage Rainy Day	13.6	11.6	10.8	9.7	7.9	4.0	1.4	1.1	3.1	6.8	10.1	13.6	93.7
Monthly Average Precipitation (mm)	127.0	107.1	77.7	55.6	39.7	19.6	9.9	9.3	19.8	51.8	89.2	137.7	744.4

3.3 Soil Physicochemical Properties in the Experimental Area

The soil type of the experimental area mainly consists of clayey and loamy soil (38% clay, 32% sand, and 30% silt). The organic matter ratio is 1.8% with a pH of 7.1, and its electroconductivity is 0.398 $\mu\text{m}/\text{cm}^2$.

3.4 Fertilizer Application and Soil Analysis

Since the almond farm has an automatic irrigation system, all nutrients except solid organic fertilizers and soil regulators are applied by fertigation. UAN-32 was used as a nitrogen source, potassium nitrate as a potassium and nitrogen source, and phosphoric acid as a phosphorus source. The fertilization planning is as follows:

Table 3.2. Monthly fertilizer application in the experimental area from 2019 to 2020

Fertilization	UAN-32(%32 N)	Potassium Nitrate	Phosphoric Acid (H₃PO₄)
	g/tree	g/tree	g/tree
January			
February	40	20	20
March	60	40	
April	70		
May		60	
June	70		
July		80	
August	45		
September	30	15	
October	30	30	
November			20
December			25
Total	345	245	65

The fertilization planning was determined according to the soil analysis results after harvest.

Table 3.3. Soil analysis report of 2019 and 2020.

Soil Analysis Report			
Report No	6450336019-1332		
City/Town	Manisa	Köprübaşı	
Plant	Almond		
Soil Elements	Unit	Methods	Results
pH		Saturation	8,33
EC	ms	Saturation	0,74
CaCO3	%	Shceibler	0,21
Organic Matter	%	Walkley-Black	1,35
Structure	ml	Saturation	52,14
Total N	%		0,07
Salinity	%	Saturation	0,025
P2O5	kg/da	Olsen(Ascorbic Acid)	16,98
K2O	kg/da	A.A.S. (Asetat)	52,47
Ca	mg/kg	A.A.S. (Asetat)	6898,00
Mg	mg/kg	A.A.S. (Asetat)	757,00
Fe	mg/kg	A.A.S. (DTPA)	16,48
Zn	mg/kg	A.A.S. (DTPA)	0,55
Mn	mg/kg	A.A.S. (DTPA)	10,24
Cu	mg/kg	A.A.S. (DTPA)	5,39
B	mg/kg	Azomethin-H	NA

3.5 Plant Material Properties

Almond orchard was constructed in 2010, the distance between the trees was 6m x 5.5m. Almond varieties of Ferragnes and Ferraduel grafted on rootstocks of Seedling, GF-677, and Garnem varieties were used.

Ferragnes: This variety has a very late flowering time, and this feature is used for agricultural advantage for marketing. The trees show highly efficient and strong development and good yield. Pollination of Ferragnes variety strongly depends on other species (Pollinators: Ai, Cristomorto, Ferraduel, Ferrastar, Nonpareil, Tuono, and Texas). The variety has a hard shell, and fruit-shell efficiency is around 30-43%. Its kernel has a wide and long shape with a width/length ratio of 42% (Kester, 1990).

Ferraduel: The most highlighted properties of the Ferraduel variety are being strong and efficient during the development and having a late flowering period. Pollination of this variety requires other varieties such as Ferragnes, Tuono, and Texas. Its kernel-shell ratio is 28% and the probability of double kernel is 0-1%. The production efficiency is quite high, and it has a resistance against *Monilia* but weak against necrosis. This variety is not commonly used as the main variety in the orchards. It usually serves as a pollinator to Ferragnes variety.

Garnem Rootstock; Garnem (*Prunus amygdalus* x *P.persica*) is a hybrid rootstock consisting of a cross between a peach from North America and an almond from Spain. The rootstock primarily was selected for almond grafting but later it showed a perfect match with peaches and nectarines. Garnem (GN 15) rootstock shows similar or slightly better development compared to GF-677 rootstock. The shape of leaves comes from almond and peach varieties' characteristics, being relatively bigger and reddish. Garnem has a high tolerance to drought and non-fertile soil but its tolerance against iron chlorosis is lower than its counterpart GF-677 rootstock. The grafting efficiency is higher in Garnem than in GF-677. Garnem shows low tolerance against asphyxia if the soil is watered excessively. It shows high tolerance against root nematodes such as *Meloidogyne arenaria*, *M. hispanica*, *M. incognita*, and *M. javanica*. On the other hand, it shows low resistance to the nematode *Pratylenus vulnus*. In agricultural areas where nematodes are encountered, Garnem rootstock is selected instead of GF-677, but it shows high sensitivity in wet soil and/or clayey soil.

GF-677 Rootstock; GF-677 (*P. persica* x *P. amygdalus*) rootstock is a hybrid of *P. persica* (almond) and *P. amygdalus* (peach), which was developed in France in the mid-1940s. Recently, GF-677 rootstock has been used widely for the grafting of almonds and peach. The rootstock is most used in the southeast region of Turkey. GF-677 development is very efficient and strong compared to its counterpart, the Seedling variety. The rootstock is compatible with heavy, middle, or light soil characteristics and they may even grow very efficiently in soils where 12-13% of clay exists. The iron chlorosis resistance of the rootstock is quite high, and it is very suitable for the areas where is dry, clayey, and inclined. Varieties grafted to this rootstock start the production very early and show high resistance to *Verticillium*

and *Phytophthora* soil-origin diseases. The best production method for the GF-677 is green-cutting and plant tissue culture (Rom and Carlson, 1987; Gür, 2003).

Seedling Rootstock; It is very compatible with dry, deep, and well drainage areas. It shows high tolerance to clayey soil and boron content. The rootstock is sensitive to root nematodes, *Agrobacterium tumefaciens*, and *Armillaria*. The root system has a high anchoring capacity.

3.6 Sampling

The plant materials are young leaves and kernels of Ferragnes and Ferraduel almond cultivars grafted on different rootstocks (such as Garnem, GF 677, and seedling rootstock), which were collected from Köprübaşı town in Manisa city. The kernels of almond cultivars were harvested in the early-mid September from the farm in the Köprübaşı town in Manisa city. We sampled 500 g of almond fruit per tree. Totally 9 kg whole kernel of Ferragnes and Ferraduel almond cultivars were collected and used for further physicochemical analyses. The samples were collected over two consecutive years (2019- 2020). Three almond trees were randomly selected per variety and rootstock combination. The leaf samples were collected in late June 2019 and 2020. Kernel and nuts were harvested in mid-September.

3.7 Measurements

The total yield per tree and yield efficiency of each rootstock were calculated from the harvested samples. At each harvest, 500 g almond fruits were sampled from each tree, and fruits were used to determine pomological properties such as weight (g), length (mm), width (mm), thickness (mm), kernel yield (%).

3.8 Chemical Analysis

3.8.1 Phenolic compounds and antioxidant activity

The ferric reducing antioxidant power (FRAP) assay was applied to determine the antioxidant activity in almond extracts (Benzie and Strain, 1996). Five grams of samples were mixed with 25 mL of methanol and homogenized using an Ika Ultra-Turrax homogenizer. The homogenates were kept at +4°C and in the dark for 14–16 h and then filtered using a Whatman No. 4 filter paper. The supernatants were recovered and stored at –20°C until analysis (Thaipong et al., 2006). The total phenolic content of the almond extract was determined using the Folin-Ciocalteu method with some modifications (Swain and Hillis, 1959). The absorbance of the supernatant was recorded at 725 nm by a spectrophotometer (Bio 100, Varian, Australia). Gallic acid was used as a standard. The total phenolic content in the extract was expressed as gallic acid equivalents (GAE) in mg/100g. The absorbance of the supernatant was recorded using a spectrophotometer (Bio 100, Varian, Australia) at 593 nm. Trolox was used as a standard and the results were expressed as Trolox equivalents (μmol TE/g).

3.8.2 Fatty acids

The fatty acid composition was determined by using the lipid extracts after methylation, which forms fatty acid methyl esters (FAME), according to the IUPAC Method No: 2.301 (IUPOC, 1990) using a Hewlett Packard 6890N gas chromatograph (Agilent, Palo Alto, CA), equipped with a Supelco SP2380 capillary column (60 m x 0.25 mm i.d., 0.20 μm film thickness; Supelco, Bellefonte, PA) and flame ionization detector (FID). Fatty acidTM 37 Component FAME mix (Supelco, Bellefonte, P A) was used for the determination of fatty acid fractions. Helium was used as the carrier gas at the flow rate of 1.1 ml/min and the split ratio of 1:20. An autosampler/injector HP7683 B Series was used, and the injector and detector temperatures were 220°C. The oven temperature was programmed to 165°C for 35 min; the temperature was then elevated 5°C per min up to 195°C and kept for 15 min.

3.8.3 Mineral content

Leaf mineral concentrations were determined during the period 2019-2020. Leaf sampling was done in July. The samples were collected from the middle part of bearing shoots of the trees, i.e., three tree replications of each graft combination. Samples were dried into an oven (İzmir, Turkey) at 64°C during 3 days until constant dry weight. The mineral composition of the dried samples such as total N was determined by Kjeldahl analysis; P was analyzed by ultraviolet spectrophotometer, K by atomic emission spectroscopy, and Mg, Fe, Mn, Cu, and Zn by atomic absorption spectroscopy.

3.9 Statistical Analysis

The experiments were conducted as a completely randomized block design with three replicates, and each replicate was evaluated separately. All computation and statistical analyses were done using IBM SPSS Statistics 19.0 (IBM, NY, USA). Significant differences between the means for every treatment were determined by Duncan's multiple range test at the level of $P \leq 0.05$.

4. RESULT AND DISCUSSION

4.1 Pomological Characteristics of Almond Cultivars

4.1.1 Results of pomological characteristics of almond cultivars in the first year

Table 4.1. Pomological characteristics of shelled and kernels in the first year

Cultivar	Rootstock	Shelled				Kernel				
		Weight(g)	Lenght(mm)	Width(mm)	Thickness	Weight(g)	Lenght(mm)	Width(mm)	Thickness	Kernel Yield(%)
Ferraduel	Seedling	8.51 ^{***} a	43.42 ^{**} a	30.39 ^{**} a	18.88 ^{**} a	1.76 ^{**} a	27.62 ^{**} a	17.62 [*] a	7.76 ^{NS}	20.73 [*] b
	Garnem	6.27 c	38.79 b	26.48 b	17.88 b	1.39 b	25.29 b	16.68 b	7.43	22.57 a
	GF-677	7.47 b	41.30 ab	28.99 ab	18.73 ab	1.72 a	27.9 a	17.87 a	7.60	23.01 a
Ferragnes	Seedling	5.36 ^{**} a	40.54 ^{**} a	26.47 [*] a	17.31 ab	1.89 ^{**} a	29.59 ^{**} a	15.61 ^{**} a	8.64 [*]	35.27 [*]
	Garnem	4.62 b	38.18 b	23.64 b	16.80 b	1.53 b	28.16 b	14.39 b	7.75	33.16
	GF-677	5.57 a	39.5 ab	25.74 a	17.61 a	1.98 a	29.47 a	16.11 a	8.55	35.7

^aThe differences between the means were determined by the Duncan test according to $P \leq 0.05$ level

^{*} $P \leq 0.05$ or ^{**} $P \leq 0.01$ is considered significant, or NS non-significant

Table 4.1 shows the effect of different rootstocks on pomological characteristics in Ferragnes and Ferraduel almonds in the first year of the experiment.

The effects of different rootstocks on fruit weight, fruit length, fruit width, and fruit thickness were found to be significant in shelled almonds ($P \leq 0.01$). First-year, shelled weights were found to be the highest (8.51 g) in the Ferraduel cultivar grown on seedling rootstock. This rootstock was followed by the GF-677 (7.47 g), while shelled weight (6.27 g) obtained from the Garnem rootstock was the lowest. While the effect of rootstocks was found to be significant on the kernel weights ($P \leq 0.01$), the kernel weights of the seedlings (1.76 g) and the GF-677 (1.72) rootstocks were found to be the highest. Kernel weight (1.39 g) was found to be low in the Ferraduel almonds on the Garnem rootstock (Table 4.1).

Shelled weight of GF-677 rootstock was 12.22% less than seedling rootstock, and the kernel yield rate was 2.28% higher. Kernel yield rates of the Ferraduel almonds were determined as 20.73% on seedling rootstock, 22.57% on the Garnem rootstock, and 23.01% on GF-677 rootstock. The kernel yield rate of both clone rootstocks was found higher compared to the seedling rootstock.

The fruit length was found to be the highest with 43.42 mm in the Ferraduel cultivar and was followed by the GF-677 (41.30 mm) and the Garnem (38.79 mm) rootstocks, respectively. In the same way, the fruit width obtained from the seedling rootstock was the largest (30.39 mm) and these rootstocks were followed by the GF-677 (28.99 mm) and the Garnem rootstocks (26.48 mm). The same order occurred in the thickness of the fruit, but the thicknesses of the almond fruits grown on all three rootstocks were found to be close to each other.

When the kernel characteristics of the Ferraduel cultivar were examined, the kernel weights obtained from seedling rootstock and the GF-677 rootstock were found to be the most ($P \leq 0.01$). Considering that shelled weights of the seedling rootstock are 12.22% more than the GF-677 rootstock almonds, kernel weights are expected to be more than those obtained from seedling rootstocks; It is seen that kernel weights obtained from both rootstocks are high. This shows that almonds obtained from the GF-677 rootstock have higher kernel yield rates. Kernel lengths were higher in the GF-677 and seedling rootstocks, while the Garnem rootstocks were found to be lower than these rootstocks ($P \leq 0.01$). While the effect of rootstocks on kernel fruit width was also significant ($P \leq 0.05$), the difference between kernel fruit thicknesses was not significant. It was found that the width, height, and thickness of the fruits of seedling rootstock and the GF-677 fruits were higher than those obtained from the Garnem rootstock (Table 4.1).

In the first year, the effect of the Ferragnes cultivar rootstocks on shelled weights and kernel weights was found to be significant ($P \leq 0.01$). The weights of almonds grown on the GF-677 (5.57 g) and the seedling (5.36 g) rootstocks were found to be higher than those of almonds on Garnem rootstock. Almond fruits in seedling rootstock were found to be 13.80% more than almonds in the Garnem rootstock, and almond fruits in GF-677 rootstock were found to be 17.05% more

than almonds in the Garnem rootstock. The kernel weights of the Ferragnes cultivar were determined to be quite high in almonds in the seedling rootstock (1.89 g) and the GF-677 (1.98 g) rootstock compared to the Garnem rootstock (1.53 g). The highest shelled length was obtained from almond fruits (40.54 mm) in the seedling rootstock. The shelled length of GF-677 rootstock was also found to be high (39.50 mm). The shelled length of the Garnem rootstocks was determined as 38.18 mm. The shelled width of the seedling rootstocks (26.47 mm) and GF-677 (25.74 mm) rootstocks were found to be wider, while the shelled of the Garnem rootstock were determined to be smaller (23.64 mm). The shelled thickness of Ferragnes almond was the highest with 17.61 mm in the GF-677 rootstock, followed by fruits in seedling rootstock (17.31 mm) and the Garnem rootstock (16.80 mm). The effect of rootstocks on the kernel thicknesses was found to be insignificant, while the kernel thicknesses ranged between 7.75 mm-8.64 mm. The effect of different rootstocks on the length and width of the kernels was found to be significant ($P \leq 0.01$). The length and width of kernels were higher in seedling rootstocks and the GF-677 rootstocks than in the Garnem rootstocks (Table 4.1)

The effect of rootstocks on kernel yield was significant in the Ferragnes cultivar ($P \leq 0.05$). The kernel yield ratio of the Ferragnes cultivar is quite high compared to the Ferradule cultivar. The kernel yield ratio of Ferraduel cultivar was 20.73% in almonds of seedling rootstocks, 22.57% in the Garnem, 23.01% in the GF-677, while it was 35.27%, 33.16%, 35.70% in almonds on seedling rootstocks in the Ferragnes cultivar.

When we compare the Ferragnes cultivar with the Ferraduel cultivar, the kernel fruit weights were found to be higher while the fruit weights were fewer. Compared to Ferraduel cultivar, the fruit weights of Ferragnes cultivar were found to be 37.01% lower in seedling rootstocks, 26.31% in the Garnem rootstocks, and 25.43% in the GF-677 rootstocks, while kernel weights were found to be 37.01% higher in seedling rootstocks, 26.31% in the Garnem rootstocks and 25.43% in GF-677 rootstocks.

4.1.2 Pomological characteristics of shelled and kernels in the second year

Table 4.2. Pomological characteristics of shelled and kernels in the second year

Cultivar	Rootstock	Shelled				Kernel				
		Weight(g)	Lenght(mm)	Width(mm)	Thickness	Weight(g)	Lenght(mm)	Width(mm)	Thickness (mm)	Kernel Yield(%)
Ferraduel	Seedling	6.35 ^{NS}	37.94 ^{** a}	27.51 ^{NS}	17.55 ^{NS}	1.49 ^{NS}	27.14* a	17.24* a	4.13* c	23.55 ^{NS}
	Garnem	5.86	35.76 b	26.33	16.57	1.39	25.92 b	16.24 b	4.49 b	23.85
	GF-677	5.92	37.66 ab	25.61	17.93	1.43	26.29 b	16.64 ab	4.80 a	24.18
Ferragnes	Seedling	5.41 ^{NS}	39.14 ab*	25.88 ab*	18.08 ^{NS}	1.75 a**	28.96 ^{NS}	15.84 ab*	4.33 ^{NS}	32.37*
	Garnem	4.8	38.27c	24.54 b	17.70	1.53 b	28.87	15.42 b	4.95	31.99
	GF-677	5.4	39.74 a	26.19 a	17.35	1.75 a	29.15	16.13 a	5.11	32.54

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$ level

* $P \leq 0.05$ or ** $P \leq 0.01$ denotes a statistically significant difference, or NS non significant

The effect of different rootstocks on the pomological properties of Ferragnes and Ferraduel almond fruits for the second year of the experiment is seen in Table 4.2.

In the second year, fruit weights and fruit lengths were found to be lower in both cultivars compared to the first year. Ecological factors are considered to be effective in this fact. The effect of rootstocks on shelled and kernel weights was not found to be significant in Ferraduel cultivars. Fruit weights were the highest in seedling rootstock in terms of shelled (6.35 g) and kernel (1.49 g). This was followed by the GF-677 and the Garnem respectively. The effect of rootstocks on fruit lengths in shelled and kernels was found to be significant ($P \leq 0.05$). Shelled length was found to be 37.94 mm in the seedling rootstock. 37.66 mm in the GF-677 rootstock. 35.76 mm in the Garnem rootstock. The kernel length was found to be 27.14 mm in the seedling rootstock. 26.29 mm in the GF-677 rootstock, and 25.92 mm in Garnem rootstock. Higher fruit length values were obtained in seedling and GF-677 rootstocks compared to Garnem rootstocks. While the effect of different rootstocks on fruit widths was not significant in shelled almonds. It was found to be significant in the kernel ($P \leq 0.05$). The fruit widths were found to be higher in kernels of seedling rootstock. While the effect of rootstocks on fruit

thickness was not found to be significant in shelled of the Ferraduel cultivar. The effect of rootstocks on kernel fruits was found to be significant ($p \leq 0.05$). The thicknesses of kernels grown on the GF-677 rootstock were the highest (4.80 mm) while the fruits of this rootstock were followed by those of the Garnem rootstock (4.49 mm), and the thicknesses of the fruits of seedling rootstock were found to be the lowest (4.13 mm). The effect of rootstocks on the kernel yield rate was not significant ranging from 23.55 to 24.18% (Table 4.2).

In the study where the fruit quality characteristics of Ferragnes cultivars of different rootstocks were investigated. The effect of rootstocks on shelled weight was found to be insignificant while the effect on kernel weights was found to be significant ($p \leq 0.01$). In the second year shelled weights and kernel weights were found as 5.40 g and 1.75 g respectively in the seedling and the GF-677 rootstocks of Ferragnes cultivars and they gave the same outcomes. The effect of different rootstocks on the lengths and widths of shelled was found to be significant ($p \leq 0.05$). The lengths, width, and thicknesses of shelled almonds were found to be 39.14 mm., 25.88 mm., 18.08 mm in seedling rootstocks; 39.74 mm., 26.19 mm., 17.35 mm in the GF-677 rootstocks; 38.27 mm., 24.54 mm., 17.70 mm in the Garnem rootstocks respectively. The length and width of shelled almonds were found to be the most in almonds in the GF-677 rootstock while they were found to be the lowest in almonds in the Garnem rootstock. The almonds in the seedling rootstock were between both rootstocks. The lengths and thicknesses of the inner almond fruits were found to be insignificant while their widths were found to be significant ($p \leq 0.05$). Kernel widths were found the highest in the fruits of the GF-677 rootstock (16.13 mm). The lowest in the almond fruits of the Garnem rootstock and the fruits of the seedling rootstock were between both groups. While the effect of rootstocks on kernel yield was not found to be significant. It was found to be 32.54% in the GF-677 rootstock. 32.37% in the seedling rootstock and 31.99% in the Garnem rootstock (Table 4.1 and Table 4.2).

In a study conducted in the province of Diyarbakır. The average weight of shelled almonds of the Ferraduel variety grafted on a seedling rootstock was determined to be 3.09 g in samples taken from different orchards. The shelled length was found to be 35.98 mm. the shelled width was 25.56 mm. and the shelled

thickness was 16.16 mm. In the Ferragnes variety. The weight of the shelled was determined as 2.37 g. the shelled height was 36.15 mm. the shelled width was 22.77 mm. and the shelled thickness was determined as 14.70 mm. The kernel weight was determined as 0.74 g kernel length as 25.03 mm., kernel width as 15.38 mm., kernel yield as 24.02% in Ferraduel variety. In the Ferragnes variety. The kernel length was determined as 0.84, kernel length as 26.97 mm., kernel width as 13.46 mm., kernel yield as 35.10% (Erdogmuş. 2018). In this study, which examined the effects of different rootstocks on Ferraduel and Ferragnes varieties, fruit length, fruit width, and fruit thickness were close to the values of Erdoğan (2018) in Ferraduel and Ferragnes varieties grown on seedling rootstock but the shelled weight and the kernel weight were determined as twice of this value (Table 4.1 and Table 4.2). There may be such differences in almond cultivation due to the effect of maintenance conditions and ecology. In addition, in this study the kernel yield was determined to be 20.73% in the first year. 23.55% in the second year in Ferraduel variety which was grafted on a seedling rootstock also to be 35.27% in the first year. 32.37% in the second year in Ferragnes (Table 4.1 and Table 4.2), and these results were in line with the results of Erdoğan (2018).

In another study conducted in Ceylanpınar district of Şanlıurfa province. It was found that the shelled weight of Ferragnes cultivar grafted on seedling rootstock was 5.27 g., shelled length was 31.64 mm., shelled width was 27.76 mm., shelled thickness was 17.16 mm. The kernel weight was found to be 1.54 g., kernel height was 26.29 mm., kernel width was 16.06 mm., kernel thickness was 6.93 mm. and kernel yield was found to be 29.22% (Aslan. 2015). In this study. The shelled weights of almonds belonging to the Ferragnes variety were in parallel with Aslan (2015) while their kernel weight was 15.38% higher than the average of both years. In addition, in this study shelled lengths were found to be higher compared to Aslan (2015).

Abderahmane (1990) determined the shelled weight in Ferragnes variety as 4.18 g., kernel yield as 35%, also shelled weight as 5.4 g, kernel yield as 25-28% in Ferraduel variety under Moroccan conditions. In this study, both years' average weight of Ferragnes cultivars grafted on seedling rootstock was 20.81% more than in Abderrahmane (1990) and the average weight of Ferraduel cultivars for both

years was 27.32% more, and the kernel yield ratios were compatible with each other in both studies (Table 4.1 and Table 4.2).

Kaşka et al (1998) conducted a study at the Koruklu research station in Şanlıurfa and determined that in late flowering the Ferraduel cultivar shelled weight is 6.69 g, the kernel weight is 1.56 g., the kernel yield is 23.33%. The kernel length is 25.06 mm., the kernel width is 16.02 mm., the kernel thickness is 8.89 mm. In the Ferragnes cultivar. The shelled weight is 5.06 g. the kernel weight is 1.74 g the kernel yield is 34.39%. The kernel length is 24.48 mm. the kernel width is 15.06 mm. the kernel thickness is 8.38 mm. In this study, in which the effects of different rootstocks were examined. The average weight of the shelled almonds (5.38 g) belonging to the Ferragnes variety grafted on seedling rootstocks, and the average weight of the kernels (1.82 g) and kernel yield ratios (33.50%) for both years were found to be compatible with Kaşka et al (1998). The kernel lengths and widths were similarly paralleled with Kaşka et al (1998) (Table 4.1 and Table 4.2). In another study conducted to determine the performance of different almond varieties in Kahramanmaraş conditions. The shelled weight of almonds belonging to the Ferragnes variety was found to be 5.12 g. which is similar to the present study (Yeşilkaynak. 2000).

In the present study, the kernel weights of Ferragnes cultivar grown on seedling rootstocks were determined as 1.89 g in the first year and 1.75 g in the second year with an average of 1.82 g. The weights of shelled almonds were determined as 5.36 g in the first year, 5.41 g in the second year with an average of 5.38 g, and the kernel yield was determined as 33.82% on average (Table 4.1 and Table 4.2). In another study (Nanos et al. 2002) conducted in the Ferragnes variety under full irrigation conditions. The kernel weight was found to be 1.32 g. which is lower than the results of our study. In another study. The weight of shelled in the Ferragnes variety was found to be 4.2 g, and the internal ratio was 37% (Vargas et al 1994).

In the present study, the shelled and kernel weights of almonds grown on GF-677 rootstock were found to be higher than Garnem rootstock (Table 4.1 and Table 4.2). In a study researching the effects of different rootstocks on Marinada and

Vairo varieties. The kernel weight of Marinada was determined as 1.26 g in Garnem rootstock. 1.29 g in GF-677 rootstock and 1.18 g in GF-677 rootstock; In the Vairo variety. It was determined as 1.18 g in the GF-677 rootstock (Lord et al from 2019).

In Ferraduel varieties grown on seedling rootstocks. The weight of shelled almonds averaged 7.43 g for both years. The weight of kernels was 1.62 g, and the kernel yield ratio was 22.14% (Table 4.1 and Table 4.2). In another study where the fruit characteristics of Ferraduel almond variety were determined. The shelled weight was determined as 6.86 g, the kernel weight was determined as 1.55 g, and the kernel yield was determined as 22.63%. In addition. The shelled lengths were found to be 37.78 mm. shelled widths were found to be 27.92 mm. and shelled thicknesses were found to be 18.79 mm. and these results were compatible with the present study (Gerçekcioglu and Atasever. 2020).

4.2 Fatty Acid Content of Almond Varieties

4.2.1 Fatty acid content of almond varieties in the first year

Table 4.3. Effect of Cultivars and Rootstocks on Relative Fatty Acid content (%) in the First Year

Cultivar	Rootstock	Palmitic Acid (C16:0)	Palmitoleic Acid (C16:1)	Stearic Acid (C18:0)	Oleic Acid (C18:1)	Linoleic Acid (C18:2)	Linolenic Acid (C18:3)	Oleic/Linoleic Ratio
Ferraduel	Seedling	6.34 ^{NS}	0.73 ^{NS}	1.90 ^{NS}	75.09 ^{NS}	15.62 ^{NS}	0.03* b	4.81
	Garnem	6.13	0.68	1.77	74.55	16.47	0.10 a	4.53
	GF-677	6.30	0.74	1.90	73.77	16.91	0.07 a	4.36
Ferragnes	Seedling	6.64** a	0.58* a	2.05* a	72.85** b	17.48** a	0.15 ^{NS}	4.17
	Garnem	6.25 b	0.54 b	1.96 b	75.20 a	15.69 b	0.97	4.79
	GF-677	6.11 c	0.59 a	1.80 c	75.24 a	15.89 b	0.86	4.74

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$ level

* $P \leq 0.05$ or ** $P \leq 0.01$ denotes a statistically significant difference, or NS non-significant

Palmitic acid (16.0), palmitoleic acid (16.1), stearic acid (18.0), oleic acid (18.1), linoleic acid (18.2), and linolenic acid (18.3) were determined as the main fatty acids in almond samples. In the first year, the effect of the Ferraduel variety

rootstocks on fatty acids was not significant except for Linolenic acid. Palmitic acid was found to be 6.26% in the Ferraduel variety in the first year, and the average value for Palmitoleic acid was 0.72%. The average stearic acid content was 1.86%, oleic acid was 74.47%, linoleic acid was 16.33%. When the linolenic acid content was examined, the effect of the Ferraduel variety grafted on different rootstocks was found to be significant ($P \leq 0.05$). Linolenic acid content was found to be higher in Garnem and GF-677 rootstocks than in Seedling rootstocks. Oleic/Linoleic acid ratios were between 4.36 and 4.81 in the first year (Table 4.3).

The effect of rootstocks on Palmitic acid content was found to be significant in the Ferragnes variety ($P \leq 0.01$). It was determined as 6.64% in Seedling rootstocks, 6.25% in Garden rootstocks, 6.11% in GF-677 rootstocks. Palmitoleic acid was found to be higher in the almonds grafted on Seedling and GF-677 rootstocks than in Garnem rootstocks ($P \leq 0.05$). The effect of rootstocks on stearic acid content was found to be significant with 95% confidence and determined as 2.05% in Seedling rootstock, 1.96% in Garnem rootstock, and 1.80% in GF-677 rootstock. The effect of rootstocks on the content of oleic and linoleic acids of the Ferragnes variety was found to be significant with the 99% confidence level. The oleic acid content of Garnem and GF-677 rootstocks was found to be 75%, which was higher than the oleic acid content of Seedling rootstocks (72.85%). The content of linoleic acid was found to be 17.48% in Seedling rootstocks, which was higher than in GF-677 and Garnem rootstocks. The effect of rootstocks on linolenic acid content was found to be insignificant. Oleic/Linoleic acid ratios were between 4.17 and 4.79 in the first year (Table 4.3).

4.2.2 Fatty acid content results of almond varieties in the second year

Table 4.4. Effect of Cultivars and Rootstocks on Relative Fatty Acids (%) in the Second Year

Cultivar	Rootstock	Palmitic Acid (C16:0)	Palmitoleic Acid (C16:1)	Stearic Acid (C18:0)	Oleic Acid (C18:1)	Linoleic Acid (C18:2)	Linolenic Acid (C18:3)	Oleic/Linoleic Ratio
Ferraduel	Seedling	6.33 ^{NS}	0.63 ^{NS}	2.02 ^{NS}	73.78 ^{NS}	16.90 ^{NS}	0.09 ^{NS}	4,37
	Garnem	6.21	0.60	1.87	74.45	16.54	0.09	4,50
	GF-677	6.24	0.63	1.95	74.20	16.63	0.09	4,46
Ferragnes	Seedling	6.64 ^{NS}	0.58 ^{NS}	1.94 ^{NS}	74.55 ^{NS}	16.18 ^{NS}	0.05 ^{NS}	4,61
	Garnem	6.40	0.56	1.75	74.97 a	16.00	0.07	4,69
	GF-677	6.21	0.53	1.78	74.94	16.22	0.08	4,62

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$ level

* $P \leq 0.05$ or ** $P \leq 0.01$ denotes a statistically significant difference, or NS non-significant

The effect of different rootstocks on fatty acid content in Ferraduel and Ferragnes varieties was not found to be significant for the second year. Oleic and linoleic acid ratios, which are important among fatty acids, were found between 4.37 and 4.69 (Table 4.4).

Almond quality assessment turns out to be an important feature when considering the concentration and quality of the oil. The amount of oleic acid in almond oil and the concentration of oleic/linoleic acid ratio are used as quality indicators (Kodad et al., 2006; Kodad and Socias, 2008). Since the oleic/linoleic acid ratio is important and has an anti-oxidation effect, it is used to determine the quality of kernels.

In a study of 26 almond genotypes in Turkey (Askin et al., 2007), Oleic Acid content was found between 50.41%- 81.2% depending on genotypes, Linoleic acid content between 6.21%-37.13%, Palmitic acid between 5.46%-15.78%, Stearic acid between 0.80%-3.83%, and Palmitoleic acid between 0.36%-2.52%. Research on the Pons almond variety reported that it contained 6.5% palmitic acid, 0.5% palmitoleic acid, 1.5% stearic acid, 62.5% oleic acid, and 29.0% linoleic acid

(Soler, Canellas, and Saura-Calixto 1988). It was reported that Ferragnes and Tuono almond varieties contain 5.88–6.19% palmitic acid, 0.88–0.93% palmitoleic acid, 1.85–2.09% stearic acid, 72.17–71.83% oleic acid, and 19.19–18.91% linoleic acid in their kernels (Barbera et al. 1994). In other studies of almond kernels, Woody Colony, Monterey, Padre, Butte, Nonpareil, Carmel, LeGrand, Fritz, Mission, Price, Sonora, Ne Plus Ultra, and Aldrich almond varieties were found to contain 5.0–6.4% palmitic acid, 64.7%–76.0% oleic acid and 16.3–26.9% linoleic acid (Gradziel, Mahoney, and Abdallah 2000).

4.3 Antioxidant Capacity and Total Phenol Contents of Almond Varieties

Almonds contain a significant amount of antioxidants such as phenols, flavonoids, phenolic acids, tannins, and vitamin E (Rao et al., 2012). Polyphenols, phenolic acids, flavonoids, and tannins contribute to the antioxidant properties of almonds (Milbury et al., 2006; Garrido et al., 2008). The composition and abundance of these molecules depend entirely on variation (Milbury et al., 2006; Barriera et al., 2008). Almonds contain a high content of phenolic compounds that protect fruit fatty acids from oxidative stress (Maestri et al., 2015).

Table 4.5. Effect of different rootstocks on Antioxidant Activity (μ mol TE/g FW) and Total Phenol Content in almond varieties ((mg GAE/100 g FW)

Cultivar	Rootstock	First-year		Second-year	
		Antioxidant activity	Total phenol	Antioxidant activity	Total phenol content
Ferraduel	Seedling	9.31 ^{NS}	116.46 ^{NS}	9.50 ^{NS}	133.14 ^{NS}
	Garnem	8.33	78.33	6.63	106.65
	GF-677	9.31	80.52	8.10	124.55
Ferragnes	Seedling	6.85 a*	89.45 ^{NS}	6.30 ^{NS}	94.87 a*
	Garnem	5.19 ab	63.31	5.78	75.01 ab
	GF-677	4.80 c	85.16	5.15	56.21 c

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$ level

* $P \leq 0.05$ or ** $P \leq 0.01$ shows a statistically significant difference

Antioxidants are among the most important compounds of organoleptic quality, which is directly related to the physical properties and chemical compounds of fruits. We observed that antioxidant activity was highly influenced by rootstocks. The results show that antioxidant activities differ significantly according to the combination of seedling rootstock and variety (Table 4.5).

In the analyzes conducted in the first year, significant differences were found in the combination of both varieties with rootstocks in terms of antioxidant capacity. The highest value was determined with a result of $9.31 \mu\text{mol TE/g YA}$ in the Ferraduel variety grafted on the Seedling rootstock. The antioxidant capacity of $6.73 \mu\text{mol TE/g}$, the lowest value, was obtained in the Ferraduel variety grafted on the GF rootstock, while the $8.33 \mu\text{mol TE/g YA}$ value was obtained in the rootstocks in which the Ferraduel variety was grafted on the Garnem rootstock. In Ferragnes variety almonds, $6.85 \mu\text{mol TE/g YA}$ was obtained when grafting on seedling rootstock, $5.19 \mu\text{mol TE/g YA}$ when grafting on Garnem rootstock, and $4.80 \mu\text{mol TE/g YA}$ when grafting on GF-677.

Although it was not found to be statistically different in the second year, higher antioxidant capacities were found in the samples taken from the trees of both varieties grafted on Seedling rootstock. In the analyses conducted on the Ferragnes variety, it was found that the antioxidant capacity was higher in the samples grafted on GF-677 rootstock and the Garnem rootstock as in the previous year. In the analyses performed on the Ferraduel variety, it was determined that the antioxidant capacity of the samples taken from the trees grafted on GF-677 rootstock was higher than the variety grafted on Garnem rootstock, unlike the previous analysis.

A study conducted for different genotypes of Spanish almonds found that there were differences between them.

During the thesis study, data were collected to compare both cultivar and rootstock cultivar combinations in analyses conducted on almonds in both years. The results of the first-year analysis of the rootstocks in which the Ferraduel variety was grafted were found to be 78.33 and 116.46 mg GAE/g. The total phenol content of the rootstocks grafted with Ferragnes cultivar was determined as 63.31 to 89.45

mg GAE/g. When the analysis results of the samples taken in the second year were evaluated, the total phenol content of the varieties grafted on the Seedling rootstock was again measured to be higher. Considering the data we obtained, the value of the total phenol content indicates that almonds are rich in phenol content. In a study of 10 different varieties of wild almonds, the maximum total phenolic substance content for the *A. pabotti* variety was 482.3 ± 1.22 mg GAEs/g extract, and the minimum total phenolic substance content for *A. urumiensis* was 184.1 ± 2.32 mg/g (Esfahlan and Jamei, n.d.). Another study of 10 different almond varieties showed that the phenolic content of extracts from almond kernels protecting the brown shell can range from 9.22 to 163.71 mg GAE/g (Barreira et al. 2008).

4.4 Yield

Table 4.6. The Effect of Different Rootstocks on Yield Values of Ferragnes and Ferraduel Almond Varieties (kg/tree)

Cultivar	Rootstock	First-year	Second-year
Ferraduel	Seedling	6.23 ^a ** c	6.53** c
	Garnem	14.67 a	14.93 a
	GF-677	12.13 b	12.60 b
Ferragnes	Seedling	5.73** c	6.07** c
	Garnem	15.93 a	16.76 a
	GF-677	13.16 b	13.43 b

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$ level

* $P \leq 0.05$ or ** $P \leq 0.01$ denotes a statistically significant difference, or NS non-significant

The effects of rootstocks on Ferraduel and Ferragnes cultivars showed parallel results in both years and were found to be significant according to $P \leq 0.01$ in both years (Table 4.6). The yield values of Ferraduel cultivar grown on Seedling rootstock were 6,23 kg/tree in the first year and 6,53 kg/tree in the second year, giving the lowest value compared to Garnem and GF-677 rootstock. Almonds grown in Garnem rootstock were 14,67 kg/tree in the first year and 14,93 kg /tree in the second year. The yields of Ferraduel almonds in GF-677 rootstock were found to be 15-17% less than those in Garnem rootstock. In Ferragnes cultivar, seedling rootstocks gave the lowest yield values with 5.73-6.07 kg/tree. Garnem rootstock,

on the other hand, gave the highest yield value with 15,93 kg/tree in the first year and 16,76 kg/tree in the second year. The yields of Ferraduel almonds in GF-677 rootstock have a yield value of 17.38-19.86% less than those in Garnem rootstock, and the yield value was determined as about 13 kg/tree.

4.5 Mineral Nutrient Content of Leaves and Kernels

Nitrogen (N) analyses carried out on the leaves were found to be significantly higher in samples taken from Garnem and GF-677 rootstocks grafted with the 'Ferraduel' variety with the ratio of 2.29% and 2.44%. respectively. Ferraduel x Seedling rootstock combination had a lower percentage of nitrogen compared to Ferragnes x Seedling (Table 4.4), which means that seedling rootstock's foliar nitrogen content was lower than clonal rootstocks in 2019. In 2020, Ferraduel x Seedling leaf samples caused the lowest N content even compared to 2019. Nitrogen uptake in different apple rootstock has been researched, and researchers have had significant differences between each rootstock (Aguirre et al., 2001).

Rootstock is a significant parameter influencing plant nutrient uptake from soil. Selected rootstocks may directly affect nutrient absorption according to soil structure and texture. Another important parameter is the 'cultivar' which is a key role in nutrient transportation from the root and leaves to whole plant parts. Therefore, compatible rootstock and cultivar combinations would directly affect the nutrient content within almond trees, leaves, and fruits.

Recent studies show the rootstock effect clearly observed on the mineral nutrient content. The rootstock-cultivar combination caused a significant difference in Nitrogen (N), Phosphorous (P), and Potassium (K) content in leaves of 'Kinnow Mandarin hybrid' (Ahmed et al., 2011). Plum rootstock performance is measured by survival in growth and leaf nutrient content. The researchers observed a significant effect of rootstock on nutrient content (Boyhan et al., 1995). There are significant differences in leaf and fruit contents based on rootstock variety combination.

Nitrogen fertilization should be on the period of greatest N uptake. During the period from bud to kernel yield, N stored in perennial organs is the source of Nitrogen for tree growth. The most efficient fertilization strategy is to apply fertilizer in every irrigation event in proportion to current plant demand and in a manner that retains applied fertilizer in the active root zone for as long as possible (Muhammad et al., 2017).

Table 4.7. Effect of Rootstock and Cultivar interaction on the almond leaves' nitrogen content

Cultivar	Rootstock	Leaf Nitrogen Content (%)	
		2019	2020
Ferraduel	Seedling	1,95**b	1,85**c
	Garnem	2,29a	2,24b
	GF-677	2,44a	2,55a
Ferragnes	Seedling	2,00	2,11
	Garnem	2,23	2,46
	GF-677	2,35	2,42

*The differences in the means were determined by the Duncan test according to $P \leq 0.05$ level

* $P \leq 0.05$ or ** $P \leq 0.01$ denotes a statistically significant difference, or NS non-significant

Phosphorus plays important role in every plant process that involves energy transfer. High-energy phosphate, held as a part of the chemical structures of adenosine diphosphate (ADP) and ATP, is the source of energy that drives the chemical reactions within the plant. The seedling rootstock combination of both varieties had lower levels of P content into the leaves. Phosphorus (P) content was found to be the highest at 0.35% in the 'Ferraduel' almond variety grafted on GF-677 rootstock. (Table 4.8). Mayer et al., (2015) conducted a study on the leaf nutrient content of peach on five rootstocks. They concluded that 'Aldrighi', 'Capdeboscq', 'Flordaguard', 'Nemaguard' and 'Okinawa' rootstocks did not influence P and Mn leaf content on 'Maciel' peach scion. Another study shows that excessive P concentration found in all rootstocks was attributed to excessive P fertilization in the cultivation conditions (S. Jiménez et al., 2007). Another study about almond x peach rootstock effect on mineral nutrient content showed that the P concentration was higher in 'Adafuel' and 'GF 677', intermediate on 'Cadaman' and 'Felinem' and lower on

‘Adarcias’ and ‘Garnem’ (Zarrouk et al., 2005). Our experimental results show that significant changes were observed in the rootstocks grafted by Ferraduel cultivars in both years (Table 4.8). No significant differences were observed on rootstocks grafted by the Ferragnes cultivar. 'Seedling' rootstocks influenced the leaf phosphorus concentration. When examined on an annual basis, it was found that samples taken from varieties grafted on GF-677 rootstock have a significantly high Phosphorus content. According to the analysis made in the first and second years, there is no significant difference in Ferragnes grafted rootstocks.

Table 4.8. Effect of Rootstocks and Cultivars interaction on the almond leaves' phosphorus content

		Leaf Phosphorus Content (%)	
Cultivar	Rootstock	2019	2020
Ferraduel	Seedling	0.20**c	0.16**c
	Garnem	0.33b	0.23b
	GF-677	0.35a	0.31a
Ferragnes	Seedling	0.26	0.11
	Garnem	0.22	0.21
	GF-677	0.13	0.33

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$ level

* $P \leq 0.05$ or ** $P \leq 0.01$ denotes a statistically significant difference, or NS non-significant

Ferragnes/GF-677 had the lowest level of phosphorus content in the first year. When the Ferragnes variety was examined separately, although the lowest phosphorus content was detected in the samples grafted on GF-677 rootstock, the values of both the first year and the second year were not found to be statistically different. However, the lowest phosphorus content was observed in the seedling rootstock leaves in the second year.

The potassium demand of almonds is like nitrogen. Fruit growth and kernel yield are determinants of K demand in older almond trees. Many soils in almond production areas have an appreciable amount of exchangeable K and hence the high K demand of almond may not necessarily require an immediate replacement in soils rich in native K (Muhammad et al., 2017).

The highest leaf K concentration was shown on ‘Felinem’ and the lowest on ‘Adarcias’, although differences were not significant when compared with the Adafuel, Cadaman, Garnem, and GF-677 (Zarrouk et al., 2005).

Table 4.9. Effect of rootstocks and cultivars interaction on the almond potassium content of leaves and kernels

Cultivar	Rootstock	Leaf Potassium Content (%)		Kernel Potassium Content (%)	
		2019	2020	2019	2020
Ferraduel	Seedling	1.12 ^{NS}	2.75 ^{NS}	0.64 ^{NS}	0.61*ab
	Garnem	1.73	1.79	0.59	0.67a
	GF-677	2.50	1.41	0.51	0.60b
Ferragnes	Seedling	1.85 ^{NS}	1.11 ^{NS}	0.42 ^{NS}	0.53 ^{NS}
	Garnem	2.13	1.41	0.38	0.60
	GF-677	2.17	1.42	0.49	0.57

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$ level

* $P \leq 0.05$ or ** $P \leq 0.01$ denotes a statistically significant difference, or NS non-significant

In Potassium (K) analyses, a high value of 0.67% was observed in fruit samples taken from ‘Ferraduel’ grafted on Garnem trees in the first year. Ferraduel cultivar grafted on Garnem rootstock is significantly high in Potassium (Table 4.9). The lowest value in the first year was obtained from the Ferraduel x Seedling rootstock combination. Second-year, Ferragnes x Seedling rootstock interaction had the lowest value.

Magnesium is an activator for many enzymes involved in energy transfer and growth processes. It is the central element in the structure of chlorophyll and hence has an essential role in photosynthesis (Muhammad et al., 2017).

Although Mg was significantly higher on Ferragnes x Garnem compared to other combinations in the first year, there were no observed differences in the kernel analysis (Table 4.10). The cv. ‘UFSun’ peach variety can be recommended for gardens to be established on sandy soils in a commercial sense because optimum concentrations of Ca, K, and Mg are found in leaf samples taken from trees grafted on Okinawa and Flordaguard rootstocks (Shahkoomahally et al., 2020).

Table 4.10. Effect of rootstock and cultivar interaction on the magnesium content of leaves and kernels

Cultivar	Rootstock	Leaf Magnesium Content (%)		Kernel Magnesium Content (%)	
		2019	2020	2019	2020
Ferraduel	Seedling	0.87**c	1.26 ^{NS}	0.19 ^{NS}	0.17
	Garnem	1.27a	1.15	0.19	0.19
	GF-677	1.35b	1.08	0.18	0.18
Ferragnes	Seedling	0.97	1.18	0.18 ^{NS}	0.18 ^{NS}
	Garnem	1.08	1.23	0.17	0.17
	GF-677	1.03	1.23	0.17	0.19

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$ level

* $P \leq 0.05$ or ** $P \leq 0.01$ denotes a statistically significant difference, or NS non-significant

Mg levels were observed higher in Ferraduel x Seedling kernels. Magnesium (Mg) levels did not differ in fruit samples, while was the highest in leaves taken from 'Ferraduel' grafted on Garnem trees with a rate of 1.27%. In the second year, there were no significant differences for each sample.

Zinc is an essential constituent of a large number of enzymes and proteins and plays a key function in flowering and early spring growth and in the maintenance of membrane integrity and hormone synthesis.

Zinc levels were observed to be significantly higher in leaves and kernels on Ferragnes cultivar grafted rootstock combinations compared to other combinations (Table 4.11).

The researchers found that the rootstock factor affected the uptake and supply of Zn element in the sweet cherry leaves which grafted on 'GiSelA 6' rootstock (Hrotkó et al., 2014).

Table 4.11. Effect of rootstock and cultivar interaction on the zinc content of almond's leaves and kernels

Cultivar	Rootstock	Leaf Zinc Content (ppm)		Kernel Zinc Content (ppm)	
		2019	2020	2019	2020
Ferraduel	Seedling	12.42 ^{NS}	12.53 ^{NS}	37.66 ^{NS}	30.06 ^{NS}
	Garnem	12.81	15.36	33.11	34.39
	GF-677	10.10	6.50	36.67	35.01
Ferragnes	Seedling	16.30 ^{**a}	8.09 ^{NS}	35.64 ^{*b}	31.45 ^{NS}
	Garnem	8.88b	11.45	31.01b	34.03
	GF-677	17.91a	9.69	40.94a	31.85

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$

* $P \leq 0.05$ or ** $P \leq 0.01$ is statistically significant

Zinc (Zn) content was analyzed differently in the first year leaf samples as 16.30 mg kg⁻¹, 8.88 mg kg⁻¹, and 17.91 mg kg⁻¹ in the rootstocks where 'Ferragnes' variety was grafted, respectively. The highest Zn value was obtained to be 40.94 mg kg⁻¹ in almond samples taken from the 'Ferragnes' GF-677 combination.

Copper is a component of many enzymes in the plant and plays a role in energy metabolism. In this study, Ferraduel x GF-677 combination) were higher in copper level (either in leaf and kernel samples) than other interactions (Table 4.12). One of the studies shows that the Copper content was significantly influenced by rootstocks grafted with Pistachio cultivar (Tavallali et al., 2008).

Table 4.12. Effect of rootstock and cultivar interaction on the copper content of leaves and kernels

Cultivar	Rootstock	Leaf Copper Content (ppm)		Kernel Copper Content (ppm)	
		2019	2020	2019	2020
Ferraduel	Seedling	61.09 ^{*ab}	37.60 ^{NS}	98.80 ^{NS}	106.10
	Garnem	47.80b	33.60	108.50	81.60
	GF-677	65.15a	38.50	128.00	107.50
Ferragnes	Seedling	53.00 ^{NS}	33.00 ^{NS}	110.80 ^{NS}	99.00 ^{NS}
	Garnem	33.70	35.70	87.90	95.80
	GF-677	33.50	27.00	106.70	77.00

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$ level

* $P \leq 0.05$ or ** $P \leq 0.01$ denotes a statistically significant difference, or NS non significant

In the first year, a significantly higher copper content was detected in the Ferraduel x GF-677 combination, and higher copper content was found in 2019. No significant copper content was observed in leaves and fruits in other combinations.

Manganese is important in photosynthesis and activates many enzymes in plants and a deficiency of Mn can greatly reduce the photosynthesis and yield of the crop. Besides the benefits of Manganese, it can cause damage to any plant due to toxicity. Manganese (Mn) toxicity in plants is often not a clearly identifiable disorder, and it can interfere with the absorption, transmission, and utilization of other elements such as Ca, Mg, Fe, and P (Cinelli et al., 2004). In the manganese analysis of leaves, higher manganese content was measured in rootstocks grafted with Ferraduel cultivar in the first year compared to the Ferragnes cultivar. When the rootstocks were evaluated within themselves, a significant difference was calculated only in the rootstocks in which the Ferraduel cultivar was grafted in 2019. The highest manganese level was detected in the Ferraduel cultivar grafted on seedling rootstock (Table 4.13).

Table 4.13. Effect of rootstock and cultivar interaction on the Manganese content of leaves and kernels

Cultivar	Rootstock	Leaves Manganese Content (ppm)	
		2019	2020
Ferraduel	Seedling	24.97**a	21.00 ^{NS}
	Garnem	14.76b	19.11
	GF-677	21.77a	19.14
Ferragnes	Seedling	23.44 ^{NS}	18.32 ^{NS}
	Garnem	22.23	18.21
	GF-677	21.58	18.11

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$

* $P \leq 0.05$ or ** $P \leq 0.01$ is statistically significant

First-year, Mn levels were observed as the lowest in GF-677 rootstock (Fig. 19). In the second year, the lowest levels were observed in Ferragnes x GF-677 leaves. In a study conducted on three different rootstocks on which the BC-2 FUJI apple cultivar was grafted; it was found that the leaves taken from the Bud.9

rootstock had higher manganese (Mn) but lower potassium (K) concentrations than the other rootstocks. (Fallahi et al., 2001).

Iron is involved in the chlorophyll generating process and is required for certain enzyme functions. Iron contents were not at a significantly different level for all combined samples (Table 4.14). A study on the sweet cherry reported that the rootstock differentiation had no effect on leaves' Fe concentration (Hrotkó et al., 2014). Another study on the plum trees grafted on various rootstocks showed that Fe concentrations were lower in Pixy than St. Julien leaf samples (Boyhan et al., 1995).

Table 4.14. Effect of rootstock and cultivar interaction on the Iron content of leaves and kernels

Cultivar	Rootstock	Leaf Iron Content (ppm)		Kernel Iron Content (ppm)	
		2019	2020	2019	2020
Ferraduel	Seedling	139.27 ^{NS}	87.64 ^{NS}	22.25 ^{NS}	8.94 ^{NS}
	Garnem	115.44	69.19	20.17	10.67
	GF-677	121.73	65.14	14.67	9.51
Ferragnes	Seedling	139.26 ^{NS}	58.83 ^{NS}	13.65 ^{NS}	12.74 ^{NS}
	Garnem	115.44	66.67	12.05	9.77
	GF-677	121.73	51.64	11.70	10.39

^aThe differences in the means were determined by the Duncan test according to $P \leq 0.05$

* $P \leq 0.05$ or ** $P \leq 0.01$ is statistically significant

In the first year, Fe levels were measured as the lowest in Ferragnes x Seedling, but the highest level was obtained from Ferraduel x Seedling leaf samples. Fe concentration of kernel was measured higher in Ferragnes x Garnem samples. In the second year, Fe levels were observed as the lowest in Ferragnes x GF-677 and the highest ratio was obtained from the Ferraduel x Seedling leaf samples. Fe concentration of kernel was measured higher in Ferraduel x Garnem samples. There is no statistically significant difference for both years (Table 4.14).

5. CONCLUSIONS

Almond orchards are increasing every day in the Aegean region. Seedling, Garnem, GF-677 rootstocks affected the fruit pomological characteristics, yield, fruit quality, and plant nutrient content of the ‘Ferraduel’ and ‘Ferragnes’ varieties.

It was determined by this study that rootstocks and varieties are effective in the intake of plant nutrients in almond trees. Nitrogen (N) analyses carried out on the leaves were found to be significantly higher in samples taken from Garnem and GF-677 rootstocks grafted with the ‘Ferraduel’ variety with the ratio of 2.29% and 2.44%, respectively. Phosphorus (P) content was found to be the highest at 0.35% in the ‘Ferraduel’ almond variety grafted on GF-677 rootstock. In Potassium (K) analyses, a high value of 0.67% was observed in fruit samples taken from ‘Ferraduel’ grafted on Garnem trees in the first year. Magnesium (Mg) levels did not differ in fruit samples, while was the highest in leaves taken from ‘Ferraduel’ grafted on Garnem trees with a rate of 1.27%. Zinc (Zn) content was analyzed differently in the first year leaf samples as 16.30 mg kg⁻¹, 8.88 mg kg⁻¹, and 17.91 mg kg⁻¹ in the rootstocks where ‘Ferragnes’ variety was grafted, respectively. The highest Zn value was obtained to be 40.94 mg kg⁻¹ in almond samples taken from the ‘Ferragnes’ GF-677 combination. The highest value of Copper (Cu) and Manganese (Mn) detected in the leaves was found in ‘Ferraduel’ GF-677 combinations with a concentration of 95.15 mg kg⁻¹ and 21.77 mg kg⁻¹, respectively. As a result of the analyses, it was understood that different combinations of rootstocks and varieties did not have a significant effect on the Iron (Fe) content.

Palmitic acid (16.0), palmitoleic acid (16.1), stearic acid (18.0), oleic acid (18.1), linoleic acid (18.2), and linolenic acid (18.3) were determined as the main fatty acids in almond samples. In the first year, the effect of different rootstocks on fatty acids in the Ferraduel variety was not found to be significant. In the first year, Palmitic, Palmitoleic, Stearic, and Linoleic acid contents were found to be higher in the Seedling/Ferragnes combination compared to other rootstock combinations of Ferragnes. In the second year, the effect of rootstocks on fatty acids in Ferragnes

and Ferraduel varieties was not found to be significant. It is seen that the effect of different rootstocks on fatty acids is not significant.

When the total antioxidant activities and total phenol contents are examined. Seedling/Ferraduel antioxidant activity was $9.40 \mu\text{mol TE/g FW}$ for both years. and total phenol content was $124.80 \text{ mg GAE/100 g FW}$; For Garnem/Ferraduel combination. the antioxidant activity average was $7.48 \mu\text{mol TE/g FW}$. and total phenol content was $92.46 \text{ mg GAE/100 g FW}$; For GF-677/Ferraduel combination. the antioxidant activity averaged $8.70 \mu\text{mol TE/g FW}$. and the total phenol content was $102.53 \text{ mg GAE/100 g FW}$. Antioxidant and phenol contents of seedling rootstocks were higher than GF-677 rootstock and Garnem rootstock. Among them. the rootstock with the lowest antioxidant and phenol content was Garnem.

Seedling/Ferragnes antioxidant activities average was $6.57 \mu\text{mol TE/g FW}$ for both years. total phenol content was $92.16 \text{ mg GAE/100 g FW}$; For Garnem/Ferragnes combination. antioxidant activity average was $5.48 \mu\text{mol TE/g FW}$. total phenol content was $69.16 \text{ mg GAE/100 g FW}$; For GF-677/Ferragnes combination. antioxidant activity average was $4.97 \mu\text{mol TE/g FW}$. and total phenol content was $70.68 \text{ mg GAE /100 g FW}$. Antioxidant and phenol contents of Seedling rootstocks were higher than GF-677 rootstock and Garnem rootstock. Among them. the rootstock with the lowest antioxidant and phenol content was again Garnem.

The effect of different rootstocks on the fruit characteristics of shelled and kernels in Ferragnes and Ferraduel varieties was more in the first production period. while it was limited in the second production year.

There were very obvious differences between Seedling rootstock and Garnem rootstock grafted with the Ferraduel almond variety in the first year. Ferraduel shelled weight was 26% higher than that of Garnem rootstock. and shelled length was 10.66% higher. shelled width was 12.86% higher. kernel weight was 21.02% higher. kernel length was 8.43% higher. and kernel width was 5.34% higher. The kernel yield was higher in Garnem rootstock than in Seedling rootstock. The kernel yield was 20.73% in Seedling rootstock while 22.57% in the Garnem rootstock. In

addition, the yield values of the Ferraduel variety grafted on Garnem rootstocks in the first year were 14.67 kg /tree and it was found to be quite high compared to the Seedling rootstock with a difference of 57.53%. This is a difference that can be very important from the point of view of cultivation. Although the shelled and kernel weights of Ferraduel varieties grafted on Seedling rootstock were found to be fewer than Ferraduel varieties grafted on Seedling rootstock, the high kernel yield and especially the high yield values reveal the superiority of Garnem rootstock grafted on Seedling rootstock in almond cultivation.

The differences between the pomological characteristics of almonds grown on Seedling rootstock and Garnem rootstock in the second year decreased; However, the shelled weight of Ferraduel almonds grafted on seedling rootstocks was 7.71% higher than Garnem rootstock, the shelled length was 5.74% higher, the shelled width was 4.28% higher, the kernel weight was 6.71% higher, the kernel length was 4.49% higher, the kernel width was 5.80% higher. Kernel yield was found to be the same. However, in the second year, the yield in the Garnem/Ferraduel combination was found to be 56.26% higher than in the Seedling/Ferraduel combination. High yield values are a very important parameter for producers.

When we compare Seedling/Ferraduel and GF-677/Ferraduel combinations for the first year, shelled weight, shelled length, shelled width, and kernel weight were found to be 12.22%, 4.88%, 4.60%, 2.27% higher in the Seedling/Ferraduel combination compared to the GF-677/Ferraduel combination, respectively. The kernel yield was found to be 20.73% in Seedling rootstock and 23.01% in GF-677. The kernel yield is greater in the GF-677/Ferraduel combination. The yield value was found to be 48.63% higher in the GF-677/Ferraduel combination than in the seedling/Ferraduel combination.

In the results of the second year, Seedling rootstock and GF-677 rootstock gave similar results in terms of shelled weights, kernel weights, and almond heights. In this case, it was found that there are heavier and larger almonds in terms of these properties compared to the Garnem rootstock. Kernel yield was found to be similar

in all three rootstocks. The yield value was found to be 48.17% higher in the GF-677/Ferraduel combination than in the seedling/Ferraduel combination.

When we look at Seedling/Ferraduel, Garnem/Ferraduel, GF-677/Ferraduel combinations based on pomological properties and yield values, it is seen that the weights and lengths of fruits in Seedling rootstock and GF-677 rootstock are higher than in Garnem rootstock. But in terms of yield values, the average of both years was determined as 6.38 kg/tree in the Seedling rootstock, 14.8 kg/tree in the Garnem rootstock, and 12.36 kg/tree in the GF-677 rootstock. The kernel yield average of both years of Seedling rootstock was determined as 22.14%, 23.21%, 23.59%. In this case, Ferraduel almond cultivar grafted on GF-677 rootstock can be preferred in lands where GF-677 rootstock and Garnem rootstock can be used, due to its bigger fruit pomological characteristics and higher yield.

The combined planting of the Ferraduel variety and the Ferragnes variety is quite common because they are pollinators of each other. The Ferragnes variety is a smaller variety than the Ferraduel variety.

In the first year, the shelled weight of Seedling/Ferragnes combinations was 13.80%, shelled length was 5.82%, shelled width was 10.69%, kernel weight was 19.04%, kernel length was 4.83%, kernel width was 7.81%, which are higher than the Garnem/Ferragnes combination.

In the first year, Seedling/Ferragnes and GF-677/Ferragnes combinations had almost the same shelled and kernel properties and had higher values compared to Garnem/Ferragnes combinations.

Kernel yield of Ferraduel cultivar was found to be 35.27% on Seedling rootstock, 33.16% on Garnem rootstock, and 35.70% on GF-677 rootstock in the first year. Kernel yield was found to be higher on Seedling rootstock and GF-677 rootstock.

In the second year, for the seedling/Ferragnes combinations, the shelled weight was 11.27% higher, shelled length was 2.22% higher, shelled width was

5.17% higher. the kernel weight was 12.57% higher. the kernel length was 0.31% higher and the kernel width was 2.65% higher.

The values of Seedling/Ferragnes and GF-677/Ferragnes combinations in the second year were almost the same.

Kernel yield was found to be 32.37% in Ferraduel cultivar. 31.99% in Garnem rootstock and 32.54% in GF-677 rootstock grafted on seedling rootstock for the second year. Kernel yield was higher in seedling rootstock and GF-677 rootstock in the second year.

The average yield was 5.9 kg/tree in both years in the Seedling/Ferragnes combination. 16.35 kg/tree in Garnem/Ferragnes. and 13.29 kg/tree in GF-677/Ferragnes. The yield of Garnem rootstock is high. But the yield of GF-677 rootstock is close to Garnem rootstock and its effect on kernel length is higher. Therefore. GF-677 rootstock should be preferred in Ferragnes variety in suitable lands. Although the yield values of Garnem rootstock are high. it was determined that the shelled and kernel weights and fruit lengths of GF-677 rootstock are higher than those of Garnem rootstock. Considering that the yield values of GF-677 rootstock were high. GF-677 rootstock was determined to be suitable for 'Ferragnes' and 'Ferraduel' almond cultivation. These parameters indicate great importance for the sustainable cultivation of almonds. Therefore. it is very important to establish a orchards with a selection of varieties that are grafted on the rootstock in accordance with the ecology.

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ACKNOWLEDGEMENTS

I could not have been able to conclude my dissertation without the guidance of my supervisor and the support of advisors. I am deeply grateful and appreciate my supervisor Assoc. Prof. Deniz EROĞUL and Prof. Mehmet Eşref İrget for their excellent guidance, invaluable support, and patience in finalizing this study during my difficult times. I also specially thank advisor Alptuğ ÇANTAL and my co-supervisor María del Carmen Martínez Ballesta for their unique contribution to the achievement of the purpose of this study. . I would also like to say especially thanks to Prof. Dr Murat Şeker for sharing his experiences.

My wife Sena Hazel ÇANTAL deserves special thanks for supporting and helping me to finalize the study. I am also thankful to my lovely mom Feride ÇANTAL for the motivational support provided during the study.

07 / 01 / 2022

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