Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi
Journal of Agricultural Faculty of Gaziosmanpasa University
https://dergipark.org.tr/tr/pub/gopzfd

Araştırma Makalesi/*Research Article*

JAFAG
ISSN: 1300-2910
E-ISSN: 2147-8848
(2023) 40(2) 81-88
doi:10.55507/gopzfd.1294373

Fruit Characteristics of Some Standard Apple Cultivar/Rootstock Combination in Ordu Ecology

Tarık YARILGAÇ[1], Serkan UZUN[2*] Orhan KARAKAYA[3] Umut ATEŞ[1] Burhan ÖZTÜRK[1]

1Department of Horticulture, Faculty of Agriculture, Ordu University, Ordu
2Department of Crop and Animal Production, Cilimli Vocational School, Duzce University, Düzce
3Department of Horticulture, Faculty of Agriculture, Sakarya University of Applied Sciences, 54580 Arifiye, Sakarya, Turkey
***Corresponding author's email:** serkan.uzun28@hotmail.com

Alındığı tarih (Received): 11.05.2023 Kabul tarihi (Accepted): 25.08.2023

Abstract: The main objective of this study was to evaluate the fruit quality characteristics and biochemical properties of Mondial Gala, Jeromine, and Granny Smith cultivars grafted on M9 full-dwarf clonal rootstock and Granny Smith, Fuji, Galaxy Gala, Red Chief, and Scarlett Spur cultivars grafted on MM 106 semi-dwarf clonal rootstock grown in Ordu (Türkiye) ecological conditions. During the research, fruit weight, fruit dimensional characteristics, fruit firmness, color characteristics, soluble solids content, titratable acidity, pH, vitamin C, total phenolic, total flavonoid and antioxidant activity of the cultivars were investigated. In the study, it was determined that, fruit weight, fruit firmness, SSC and Vitamin C 185.40 g (Mondial Gala/M9)-284.03 g (Scarlet Spur/MM 106), 69.73 N (Galaxy Gala/MM 106)-84.47 N (Granny Smith/M9), 8.29% (Scarlett Spur/MM 106)-14.27% (Fuji/MM 106), 58.00 mg (Scarlet Spur/MM 106)-112.33 mg (Granny Smith/M9), respectively. In addition, it was determined that Granny Smith, Red Chief, Mondial Gala, and Jeromine cultivars stand out in terms of bioactive compounds that positively affect human health compared to other cultivars. As a result, it has been revealed that apple cultivars grafted on M9 and MM 106 clone rootstocks examined in the study can be grown in high quality in Ordu ecology.

Keywords: Antioxidant, fruit firmness, *Malus domestica*, pomology, vitamin C

Ordu Ekolojisindeki Bazı Standart Elma Çeşit/Anaç Kombinasyonlarının Meyve Özellikleri

Öz: Bu çalışmanın temel amacı, Ordu (Türkiye) ekolojik koşullarında yetiştirilen M9 tam bodur klon anacı üzerine aşılı Mondial Gala, Jeromine ve Granny Smith çeşitleri ile MM 106 yarı bodur anacı üzerine aşılı Granny Smith, Fuji, Galaxy Gala, Red Chief ve Scarlett Spur çeşitlerinin meyve kalite özellikleri ile biyokimyasal içeriğini belirlemektir. Araştırmada çeşitlerin meyve ağırlığı, meyve boyutsal özellikleri, meyve sertliği, renk özellikleri, suda çözünebilir kuru madde miktarı, titre edilebilir asitlik, pH, C vitamini, toplam fenolik, toplam flavonoid ve antioksidan aktiviteleri incelenmiştir. Çalışmada meyve ağırlığı, meyve eti sertliği, SÇKM ve C vitamini içeriği sırasıyla 185.40 (Mondial Gala/M9)-284.03 g (Scarlet Spur/MM 106), 69.73 (Galaxy Gala/MM 106)-84.47 N (Granny Smith/M9), %8.29 (Scarlet Spur/MM 106)-%14.27 (Fuji/MM 106) ve 58.00 (Scarlet Spur/MM 106)-112.33 mg (Granny Smith/M9) arasında belirlenmiştir. Ayrıca Granny Smith, Red Chief, Mondial Gala ve Jeromine çeşitlerinin insan sağlığını olumlu yönde etkileyen biyoaktif bileşikler açısından diğer çeşitlere göre öne çıktığı saptanmışmıştır. Sonuç olarak, çalışmada incelenen M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin Ordu ekolojisinde kaliteli bir şekilde yetiştirilebileceği tespit edilmiştir.

Anahtar kelimeler: Antioksidan, meyve eti sertliği, *Malus domestica*, pomoloji, vitamin C

1. Introduction

Apple (*Malus domestica* Borkh.), in the *Rosaceae* family's *Malus* genus, is among the oldest cultivated pome fruit species. It is reported that the origin of apples is Anatolia, Caucasus, and Central Asia (Bayazıt et al., 2019). At the same time, it is a fruit species that can easily adapt to many regions with its high adaptability and can be produced in large areas accordingly. Due to the fact that Türkiye is among the homelands, this fruit species is cultivated intensively in the ecological conditions of our country (Ozmen & Cekic, 2018).

With the development and using of full-dwarf and semi-dwarf rootstocks in apple cultivation, modern farming techniques have started to develop rapidly. In this sense, with the application of the intensive planting systems, and the development of the training and pruning techniques in fruit trees, an increase in yield to be obtained from the unit area, which is among the most important goals of modern fruit growing, has been achieved (Dadashpour et al., 2019). Therefore, the selection of the rootstock and cultivar to be used in breeding increases its importance day by day. It is

reported that rootstocks have an equal effect on growth vigor and productivity as in grafted scions (Gjamovski & Kiprijanovski, 2011). However, when choosing rootstocks and cultivars, ecological conditions such as light, humidity, temperature, and soil structure must be considered in the regions where production will be made. It is known that these factors significantly impact yield and fruit quality based on species and cultivars (Eskimez et al., 2020).

Despite the positive developments in dwarf apple cultivation in Türkiye in recent years, it is stated that traditional approaches in terms the of training systems and pruning practices continue, so the expected yield from the orchards cannot be obtained. It is reported that the studies should be carried out to determine the yield characteristics of the popular cultivars and rootstock combinations to eliminate this situation in our country (Ozkan & Kucuker, 2009). The ecological demands of the new cultivars developed the breeding studies show differences. Therefore, it is reported that the economic losses that may occur due to the wrong cultivar can be prevented by carrying out studies on adapting these cultivars in different regions of our country (Balta et al., 2020). As a matter of fact, in recent years, many studies have been reported to determine the performance of the different apple cultivars in different regions in Türkiye (Aksoy, 2017; Balta et al., 2020; Bolat et al., 2019; Ceylan, 2008; Ozturk & Ozturk, 2016; Oztürk et al., 2016; Ozongun et al., 2014; Ozongun et al., 2016; Soylu et al., 2003; Sensoy & Bostan, 2019; Turan & Karlıdag, 2022).

This study was carried out to determine the fruit quality characteristics of the different apple cultivars grafted on M9 full-dwarf and MM 106 semi-dwarf clonal rootstocks in Ordu (Türkiye) in 2017-2018 years. The findings obtained from the study will facilitate the selection of the cultivars for the producers who aim to grow apples in the region.

2. Materials and Methods

2.1. Plant Materials

The plant material of the study consisted of Mondial Gala, Jeromine, and Granny Smith cultivars grafted on M9 dwarf rootstock; Granny Smith, Fuji, Galaxy Gala, Red Chief, and Scarlett Spur cultivars grafted on MM 106 semi-dwarf rootstock in Ordu University, Faculty of Agriculture, Application and Research Center. Trees were planted with 3.0 x 1.2 m between rows and trained with the central leader system for M9 rootstock; 3.5 x 3.0 m between rows and pruned with the goble system for MM 106. Irrigation is done with a double-line drip irrigation system with 2 L/h drippers, and other cultural processes are also applied regularly.

2.2. Methods

The experiment was designed according to the completely randomized plots with three replications and four trees in each replication. Considering the planting year, trees with similar growth vigor were selected. Measurements and analyzes were carried out on trees in 2017 (3 years old) and 2018 (4 years old). However, since the fruit set did not occur in Fuji, Galaxy Gala, Red Chief, and Scarlett Spur cultivars grafted on MM 106 rootstock in 2017, these characteristics could not be examined.

2.2.1. Physical characteristics

Fruit weight (g) was determined with a digital precision scale (Desis, Türkiye) with an accuracy of 0.01 grams. Fruit sizes were determined by measuring with a digital caliper (Mitutoyo, Japan) with a sensitivity of 0.01 mm. Fruit firmness was determined with a penetrometer (FT-327, Italy) using an 11.1 mm tip by measuring two different places where the skins were peeled from the equatorial region of the fruit. Measurements were performed on 10 fruit for each replication. The skin color of the fruit (10 fruit) was determined using a colorimeter (Minolta, model CR-400, Tokyo, Japan) in CIE L*, a*, b*, chroma, and hue angle (McGuire, 1992).

2.2.2. Soluble solids content (SSC), titratable acidity (TA), pH and vitamin C

SSC was determined with a digital refractometer (PAL-1, McCormick Fruit Tech. Yakima, ABD) from the juice sample obtained without sediment from the fruit. According to Oztürk et al. (2016), TA was calculated in terms of malic acid. Vitamin C was determined using a reflectometer set (Merck RQflex plus 10, Germany).

2.2.3. Biochemical characteristics

To determine the total phenolics in the study, 600 µl of fresh fruit extract from each sample was diluted with 4.2 ml of distilled water. After adding 100 µl of Folin-Ciocalteu's reagent and 300 µl of 2% sodium carbonate (Na_2CO_3), the prepared solution was incubated for 30 minutes. Then, it was measured at 760 nm in a UV-Vis spectrophotometer (Shimadzu, Kyoto, Japan), and the results were calculated in gallic acid (mg GAE 100 g^{-1} fw) (Aglar et al., 2019). To determine the total flavonoid content, 500 µl of the extract from each sample was

diluted with 3.8 ml of methanol and 100 µl of ammonium acetate ($C_2H_7NO_2$). Then 100 µl of ammonium nitrate (NH_4NO_3) was added. After the prepared solution was incubated for 40 minutes, it was measured at 415 nm, and the results were presented as quercetin equivalents (mg QE 100 g^{-1} fw) (Chang, et al., 2002). The antioxidant activity was determined according to two different procedures of 2,2-diphenyl-1-picryl-hydrazyl-hydrate (DPPH) (Blois, 1958), and Ferric Ions (Fe^{+3}) Reducing Antioxidant Power (FRAP) (Benzie & Strain, 1996), and the results were expressed in µmol Trolox equivalent (TE) kg^{-1} fw.

2.4. Statistical Analysis

The data obtained from the experiment were analyzed in the JMP 16.0 software, and the 'Tukey Multiple Comparison Test' ($p<0.05$) was used to compare the differences between the means. Principal components and biplot graphs were constituted using fruit physical and color characteristics, and biochemical content determined in the rootstock/cultivar combinations investigated.

3. Results and Discussion

In the study, the fruit weight and fruit firmness varied between 185.40 g (Mondial Gala/M9)-284.03 g (Scarlet Spur/MM 106) and 69.73 N (Galaxy Gala/MM 106)-84.47 N (Granny Smith/M9), respectively (Table 1). The differences between the cultivars in fruit weight and fruit firmness were found to be statistically significant ($p<0.05$). Fruit weight and fruit firmness were important criteria in terms of commercial value in apples. The highest fruit weight was obtained in Scarlet Spur/MM 106 cultivar in the study, followed by Red Chief/M9 and Granny Smith/M9 cultivars. In terms of fruit firmness, the highest values were obtained from Granny Smith/M9, Granny Smith/MM 106, and Fuji/MM 106 cultivars. In a study carried out in Çarşamba (Samsun) ecological conditions, it was reported that the highest fruit weight and firmness were obtained from the Granny Smith cultivar as 187.7 g and 86.11 N, respectively (Balta et al., 2020). Oztürk et al. (2016), in their study conducted in Ordu province, reported the fruit weight was between 136.2 (Red Chief)-207.1 g, and the fruit firmness was between 63.43 (Mondial Gala)-82.83 N (Red Chief). In the measurements performed for fruit size, the fruit width of the cultivars was between 70.22 (Mondial Gala/M9)-82.52 mm (Red Chief/MM 106), the fruit thickness was between 63.02 (Mondial Gala/M9)-89.37 mm (Scarlet Spur/MM 106), and the fruit length was between 64.30 (Mondial Gala/M9)-74.83 mm (Granny Smith/M9) (Table 2). The differences between the cultivars in fruit size values were found to be statistically significant ($p<0.05$). In previous studies, the dimensional fruit characteristics have been reported; in the study carried out in Niğde conditions, fruit width was 70.09 (Galaxy Gala/M9)-75.86 mm (Granny Smith/M9), fruit length was 57.55 (Mondial Gala/M9)-66.68 mm (Granny Smith/M9) Ceylan (2008); in a study conducted in Ordu province, fruit width was 67.41 (Red Chief) - 77.60 mm (Granny Smith), fruit length was 58.65 (Red Chief) - 69.07 mm (Granny Smith) (Öztürk et al., 2016); in Çarşamba region, fruit width was 70.74 (Royal Gala)-74.34 mm (Granny Smith), fruit width was 72.67 (Royal Gala)-76.91 mm (Granny Smith) and fruit length was 62.29 (Royal Gala)-65.90 mm (Granny Smith) (Balta et al., 2020). It has been observed that the cultivars examined in terms of fruit weight have relatively higher values than other studies, and they have similarities in fruit firmness and fruit size. It is thought that the observed differences may be due to ecological factors, cultivar/rootstock differences and cultural practices.

Table 1. Fruit weight and firmness values of apple cultivars grafted on M9 and MM 106 clonal rootstocks
Çizelge 1. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin meyve ağırlığı ve sertlik değerleri*

Cultivar/Rootstock	Fruit weight (g)			Fruit firmness (N/mm)		
	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	184.14	186.66	185.40 c	79.99	63.46	71.72 c
Jeromine/M9	175.30	271.95	223.63 bc	80.07	67.94	74.01 c
Granny Smith/M9	196.21	282.22	239.21 abc	87.57	81.38	84.47 a
Granny Smith/MM 106	165.84	234.22	200.03 bc	87.68	80.92	84.30 a
Fuji/MM 106	nd*	205.81	205.81 bc	nd	83.06	83.06 ab
Galaxy Gala/MM 106	nd	197.87	197.87 bc	nd	69.73	69.73 c
Red Chief/MM 106	nd	250.14	250.14 ab	nd	71.84	71.84 c
Scarlet Spur/MM 106	nd	284.03	284.03 a	nd	69.80	69.80 c

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Table 2. Fruit width, thickness and length of apple cultivars grafted on M9 and MM 106 clonal rootstocks
Çizelge 2. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin meyve eni, kalınlığı ve boyu*

Cultivar/Rootstock	Fruit width (mm)			Fruit thickness (mm)			Fruit length (mm)		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	66.13	74.31	70.22 b	60.80	65.25	63.02 e	55.56	73.05	64.30 b
Jeromine/M9	74.84	83.58	79.21 a	68.91	88.61	78.76 bc	62.49	74.10	68.30 ab
Granny Smith/M9	75.51	84.20	79.85 a	74.29	87.60	80.94 abc	70.60	79.06	74.83 b
Granny Smith/MM 106	76.02	82.79	79.40 a	73.59	80.21	76.90 bc	70.76	72.86	71.81 ab
Fuji/MM 106	nd*	79.07	79.07 a	nd	65.67	70.24 cd	nd	64.47	64.47 b
Galaxy Gala/MM 106	nd	76.67	76.67 ab	nd	65.67	65.67 de	nd	74.94	74.94 a
Red Chief/MM 106	nd	82.52	82.52 a	nd	85.79	85.79 ab	nd	68.90	68.90 ab
Scarlet Spur/MM 106	nd	78.98	78.98 a	nd	89.37	89.37 a	nd	74.71	74.71 a

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Table 3. L*, a*, b* values of apple cultivars grafted on M9 and MM 106 clonal rootstocks
Çizelge 3. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin L*, a*, b* değerleri*

Cultivar/Rootstock	L*			a*			b*		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	56.92	56.56	56.74 a	23.89	23.31	23.60 ab	28.17	25.73	26.95 c
Jeromine/M9	32.15	37.69	34.92 d	18.63	21.18	19.91 b	8.78	13.83	11.31 e
Granny Smith/M9	54.03	60.07	57.05 a	-18.98	2.84	-8.07 d	38.20	30.43	34.31 b
Granny Smith/MM 106	55.72	60.84	58.28 a	-19.46	-59.77	-19.69 e	40.03	41.45	40.74 a
Fuji/MM 106	nd	61.46	61.46 a	nd	3.57	3.57 c	nd	30.89	30.89 bc
Galaxy Gala/MM 106	nd	50.65	50.65 b	nd	30.35	30.35 a	nd	26.44	26.44 c
Red Chief/MM 106	nd	44.23	44.23 c	nd	21.28	21.28 b	nd	21.13	21.13 d
Scarlet Spur/MM 106	nd	40.68	40.68 cd	nd	21.90	21.90 ab	nd	18.89	18.89 d

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Table 4. Chroma and hue angle of apple cultivars grafted on M9 and MM 106 clonal rootstocks
Çizelge 4. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin chroma ve hue açısı*

Cultivar/Rootstock	Chroma			Hue Angle		
	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	40.89	35.39	38.14 b	52.37	49.32	50.85 d
Jeromine/M9	20.72	25.35	23.03 e	24.77	33.05	28.91 e
Granny Smith/M9	42.67	30.71	36.69 bc	116.42	84.45	100.43 b
Granny Smith/MM 106	44.53	45.99	45.26 a	115.96	115.67	115.81 a
Fuji/MM 106	nd	31.50	31.50 cd	nd	83.00	83.00 c
Galaxy Gala/MM 106	nd	40.90	40.90 ab	nd	41.36	41.36 de
Red Chief/MM 106	nd	30.21	30.21 d	nd	44.93	44.93 d
Scarlet Spur/MM 106	nd	29.36	29.36 d	nd	40.41	40.41 de

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

The differences between the cultivars in fruit color characteristics were found to be statistically significant ($p<0.05$). In the measurements to determine the fruit color, the L* value was found between 34.92 (Jeromine/M9)-61.46 (Fuji/MM 106), a* value was found between -19.69 (Granny Smith/MM 106)-30.35 (Galaxy Gala/MM 106), b* value was found between 11.31 (Jeromine/M9)-40.74 (Granny Smith/MM 106), C* was found between 23.03 (Jeromine/M9)-40.90 (Galaxy Gala/MM 106), and hue angle was found between 28.91 (Jeromine/M9)-115.81 (Granny Smith/MM 106) (Table 3, Table 4). Fruit color is one of the main features that directly affect consumer preference. The L* value represents the brightness of the fruit color. In the study, the brightest varieties of fruit skin were Fuji/MM 106, Granny Smith/MM 106, Granny Smith/M9 and Mondial Gala/M9. The a* value indicates the red-green color of the fruit. In this context, Galaxy Gala/MM 106, Mondial Gala/M9 and Scarlet Spur/MM 106 cultivars were the most red-colored, while Granny Smith/MM 106 and Granny Smith/M9 had green-colored fruit. The chroma value (C*) refers to the saturation of the color and defines the vividness or dullness of the color (Uzun & Ozturk, 2020). The cultivars with the highest C* value in the study were Granny Smith/MM 106 and Galaxy Gala/MM 106 cultivars. When the hue angle values were examined, it was seen that the hue angle values of the red-colored cultivars (Mondial Gala, Jeromine, Fuji, Galaxy Gala, Red Chief, Scarlet Spur) were lower than the green-colored Granny Smith cultivar combinations. Similarly, Ozturk & Ozturk (2016) reported that the hue angle was lower in red varieties than in varieties such as Granny Smith and Golden Delicious.

Table 5. Soluble solids content and titratable acidity values of apple cultivars grafted on M9 and MM 106 clonal rootstocks

Çizelge 5. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin suda çözünebilir kuru madde içeriği ve titre edilebilir asitlik değerleri*

Cultivar/Rootstock	SSC %			TA, % malic acid		
	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	13.53	11.57	12.55 b	0.39	0.31	0.35 cd
Jeromine/M9	12.23	12.47	12.35 b	0.69	0.34	0.52 c
Granny Smith/M9	12.10	12.37	12.23 b	1.46	1.13	1.29 a
Granny Smith/MM 106	13.28	11.03	12.16 b	1.24	0.85	1.05 b
Fuji/MM 106	nd	14.27	14.27 a	nd	0.39	0.39 cd
Galaxy Gala/MM 106	nd	11.77	11.77 b	nd	0.32	0.32 cd
Red Chief/MM 106	nd	11.87	11.87 b	nd	0.24	0.24 d
Scarlet Spur/MM 106	nd	8.29	8.29 c	nd	0.25	0.25 d

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Table 6. pH and vitamin C of apple cultivars grafted on M9 and MM 106 clonal rootstocks

Çizelge 6. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin pH ve C vitamini*

Cultivar/Rootstock	pH			Vitamin C mg 100 g^{-1}		
	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	4.29	3.96	4.12 b	93.00	69.33	81.17 cd
Jeromine/M9	4.59	4.36	4.48 a	66.33	68.00	67.17 ef
Granny Smith/M9	3.96	3.53	3.75 c	102.00	122.67	112.33 a
Granny Smith/MM 106	4.01	3.70	3.86 c	97.50	97.00	97.25 b
Fuji/MM 106	nd	3.98	3.98 bc	nd	78.67	78.67 de
Galaxy Gala/MM 106	nd	3.99	3.99 bc	nd	76.00	76.00 de
Red Chief/MM 106	nd	4.23	4.23 ab	nd	92.00	92.00bc
Scarlet Spur/MM 106	nd	4.48	4.48 a	nd	58.00	58.00 f

*nd, non-defined. The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Chemical properties are among the most important factors affecting the taste formation of products. In addition, it is stated that the products contribute to issues such as tolerance to stress factors and post-harvest physiology (Eskimez et al., 2020). Therefore, it is important to identify these features. Soluble solids content and titratable acidity values determined in cultivars are presented in Table 5, pH and vitamin C values are shown in Table 6.

The differences between the cultivars in SSC, TA, pH content, and Vitamin C were found to be statistically significant ($p<0.05$). Additionally, the SSC content was between 8.29% (Scarlett Spur/MM 106)-14.27% (Fuji/MM 106); TA content was between 0.24% (Red Chief/MM 106)-1.29% (Granny Smith/M9); pH content was between 3.75 (Granny Smith/M9)-4.48 (Jeromine/M9, Scarlet Spur/MM 106); and Vitamin C was between 58.00 mg (Scarlet Spur/MM 106)-112.33 mg (Granny Smith/M9). Accordingly, the cultivars with the highest vitamin C content were determined as Granny Smith/M9, Granny Smith/MM 106, Red Chief/MM 106, and Mondial Gala/M9, respectively. In previous studies, SSC, TA, and pH were reported; in Görükle conditions, SSC 12.9-15.8%, TA content 0.25-0.96%, pH 3.15-4.04 (Soylu et al., 2003); in Ordu conditions, SSC 9.13-11.25%, TA content is 0.27-0.67%, pH 3.23-3.82 (Oztürk et al., 2016); in Hatay conditions, SSC 11.38-14.83%, TA content 0.49-1.27%, pH 3.14-3.67, (Bayazit & Caliskan, 2017). Accordingly, the SSC, pH, and TA contents of the cultivars examined in the study were compatible with the literature.

The differences between the cultivars in total phenolics, total flavonoids, and total antioxidant capacity were found to be statistically significant ($p<0.05$). The total phenolics content in the cultivars varied between 102.88 mg 100 g^{-1} (Galaxy Gala/MM 106)-347.62 mg 100 g^{-1} (Red Chief/MM 106), the total flavonoid content between 20.31 mg 100 g^{-1} (Mondial Gala/M9)-186.97 mg 100 g^{-1} (Granny Smith/MM 106), and the total antioxidant activity varied between 980.2 µmol kg^{-1} (Fuji/MM 106)-2298.9 µmol kg^{-1} (Red Chief/MM 106) according to the DPPH test and between 2025.7 µmol kg^{-1} (Galaxy Gala/MM 106)-8214.0 µmol kg^{-1} (Mondial Gala/M9) according to the FRAP test (Table 7). Many studies determined apples' phenolic compound, total flavonoid, and antioxidant activity (Candrawinata et al., 2014; Kammarer et al., 2007; Marinova et al., 2005; Oztürk et al., 2016; Yue et al., 2012). Apples are known as an essential source of natural antioxidants thanks to vitamin C, flavonoids, and phenolic compounds found in their structure (González-Aguilar et al., 2008). Depending on these properties, when consumed regularly, it can help prevent some chronic diseases such as asthma, diabetes, and diseases

such as heart diseases and cancer, and protect human health (Boyer & Liu, 2004). In the study, the highest values regarding total phenolics were determined in Red Chief/MM 106, Granny Smith/MM 106, Mondial Gala/M9, and Granny Smith/M9 combinations, respectively. The highest values in terms of total flavonoids were determined in Granny Smith/MM 106, Granny Smith/M9, Galaxy Gala/MM 106, and Jeromine/M9 combinations. Butkeviciute et al. (2022) reported that proper matching of cultivar-rootstock combinations influenced the production of antioxidant-rich, high-quality, and nutritious fruits. According to the DPPH assay, the highest total antioxidant activity was found in Red Chief/MM106, Jeromine/M9, Mondial Gala/M9, and Granny Smith/M9 combinations, respectively; it was determined in Mondial Gala/M9, Red Chief/MM106, Granny Smith/M9, and Jeromine/M9 combinations according to FRAP assay.

Table 7. Total phenolics, total flavonoids and antioxidant activity of apple cultivars grafted on M9 and MM 106 clonal rootstocks

Çizelge 7. *M9 ve MM 106 klon anaçları üzerine aşılı elma çeşitlerinin toplam fenol, toplam flavonoid ve antioksidan aktivitesi*

Cultivar/Rootstock	Total phenolics (mg 100g^{-1})	Total flavonoids (mg 100 g^{-1})	Total antioxidant activity	
			DPPH (µmol kg^{-1})	FRAP (µmol kg^{-1})
Mondial Gala/M9	286.08 bc	20.31 f	1771.0 b	8242.0 a
Jeromine/M9	252.02 de	108.12 d	2159.5 a	6713.0 c
Granny Smith/M9	270.74 cd	148.52 b	1688.7 bc	7854.0 ab
Granny Smith/MM 106	301.30 b	186.97 a	1413.2 d	7501.0 b
Fuji/MM 106	229.35 e	99.24 d	980.2 e	3750.5 e
Galaxy Gala/MM 106	102.88 g	131.81 c	1440.3 d	2025.7 f
Red Chief/MM 106	347.62 a	104.18 d	2298.9 a	8072.0 ab
Scarlet Spur/MM 106	176.13 f	79.01 e	1540.6 cd	4620.2 d

The difference between the means with the same letter in the same column is not significant ($p<0.05$).

Figure 1. Component plot of the two-principal component in the investigated apple cultivars based on fruit properties and bioactive compounds

Şekil 1. *Meyve özellikleri ve biyoaktif bileşiklere bağlı olarak incelenen elma çeşitlerinde iki temel bileşenin bileşen grafiği*

As a result of principal component analysis, four components with an eigenvalue above one was formed. The first three components formed explained 82.1% of the data. PC 1 was associated with SSC, TA, vitamin C, pH, firmness, L*, a*, b*, chroma, hue angle, and total flavonoids, accounting for 45.1% of the data. PC 2, explaining 21.5% of the data, was related to fruit weight, fruit width, and fruit thickness. PC 3 is related to fruit length, total phenolics, and antioxidant activity (according to DPPH and FRAP) and explained 15.5% of the data (Figure 1).

4. Conclusion

The study showed that Mondial Gala, Jeromine, and Granny Smith cultivars grafted on M9 rootstock and Granny Smith, Fuji, Galaxy Gala, Red Chief, and Scarlet Spur apple cultivars grafted on MM 106 rootstock gave successful results in Ordu province ecology in terms of fruit characteristics. Fruit weight, which significantly affects consumer preference, was found to have the highest values in Scarlet Spur/MM 106, Red Chief/MM 106, and Granny Smith/M9 combinations; and fruit firmness was found to have the highest values in Granny Smith/M9, Granny Smith/MM 106, and Fuji/MM 106 combinations. In terms of bioactive properties that positively affect human health, it can be said that total phenolics stand out in the Red Chief/MM 106 combination and total flavonoids in the Granny Smith/MM 106 combination. In addition, it was determined that the antioxidant activity gave better results in Red Chief/MM 106 and Jeromine/M9 combinations according to the DPPH assay, and in Mondial Gala/M9, Red Chief/MM 106 and Granny Smith/M9 combinations according to the FRAP assay compared to other cultivars. Accordingly, it is thought that the findings obtained from the study are promising, and it will be helpful to examine the performances of these cultivars in the local ecology for a long time.

Acknowledgment

This study was supported by Ordu University Scientific Research Projects Unit (ODU-BAP) with the project numbered AP-1707.

References

Aglar, E., Saracoglu, O., Karakaya, O., Ozturk, B., & Gun, S. (2019). The relationship between fruit color and fruit quality of sweet cherry (*Prunus avium* L. cv. '0900 Ziraat'). *Turkish Journal of Food and Agriculture Sciences*, 1(1), 1-5.

Aksoy, B. (2017). Çarşamba'da M9 anacı üzerine aşılı bazı elma çeşitlerinin (Granny Smith, Royal Gala ve Galaxy Gala) verim ve bazı meyve kalite özelliklerinin incelenmesi (Tez No. 484435). [Yüksek lisans tezi, Ordu Üniversitesi]. Yükseköğretim Kurulu Başkanlığı, Ulusal Tez Merkezi.

Balta, M. F., Aksoy, B., Karakaya, O., & Uzun, S. (2020). Çarşamba ekolojik koşullarında yetiştirilen bazı standart elma çeşitlerinin verim ve meyve özellikleri. *Akademik Ziraat Dergisi*, 9(2), 187-192. https://doi.org/10.29278/azd.720106

Bayazıt, S., Kılıç, D., & Gündüz, K. (2019). Performance of Mondial Gala apple cultivars grafted on M9 apple rootstock in the Mediterranean region of Turkey. *Mustafa Kemal Üniversitesi Tarım Bilimleri Dergisi*, 24(1), 43-47.

Benzie, I. F., & Strain, J. J. (1996). The ferric reducing ability of plasma (FRAP) as a measure of "antioxidant power": The FRAP assay. *Analytical Biochemistry,* 239(1): 70-76. https://doi.org/10.1006/abio.1996.0292

Blois, M. S. (1958). Antioxidant determinations by the use of a stable free radical. *Nature*, 181(4617), 1199-1200. https://doi.org/10.1038/1811199a0

Bolat, İ., Yılmaz, M., & İkinci, A. (2019). Akdeniz geçit kuşağında farklı dönemlerde olgunlaşan bazı elma çeşitlerinin performanslarının belirlenmesi. *Yuzuncu Yıl University Journal of Agricultural Sciences*, 29(2), 258-267. https://doi.org/10.29133/yyutbd.471552

Boyer, J., & Liu, R. H. (2004). Apple phytochemicals and their health benefits. *Nutrition journal*, 3, 1-15. https://doi.org/10.1186/1475-2891-3-5

Butkeviciute, A., Abukauskas, V., Janulis, V., & Kviklys, D. (2022). Phenolic content and antioxidant activity in apples of the 'Galaval' cultivar grown on 17 different rootstocks. *Antioxidants*, 11(2), 266. https://doi.org/10.3390/antiox11020266

Candrawinata, V. I., Golding, J. B., Roach, P. D., & Stathopoulos, C. E. (2014). Total phenolic content and antioxidant activity of apple pomace aqueous extract: Effect of time, temperature and water to pomace ratio. *International Food Research Journal*, 21(6), 2337-2344.

Ceylan, F. (2008). Bodur ve yarı bodur anaçlar üzerine aşılı bazı elma çeşitlerinin Niğde ekolojik şartlarında fenolojik ve pomolojik özelliklerinin tespiti (Tez No. 178302). [Yüksek lisans tezi, Selçuk Üniversitesi]. Yükseköğretim Kurulu Başkanlığı, Ulusal Tez Merkezi.

Dadashpour, A., Talaie, A. R., Askari-Sarcheshmeh, M. A., & Gharaghani, A. (2019). Influence of two training systems on growth, yield and fruit attributes of four apple cultivars grafted onto 'M. 9'rootstock. *Advances in Horticultural Science*, 33(3), 313-320. https://doi.org/10.13128/ahs-23353

Eskimez, İ., Polat, M., & Mertoğlu, K. (2020). M9 anacı üzerine aşılı Arapkızı, Jonagold ve Fuji Kiku elma (*Malus domestica* Borkh.) çeşitlerinin Isparta ekolojik koşullarında fenolojik ve fiziko-kimyasal özellikleri. *Uluslararası Tarım ve Yaban Hayatı Bilimleri Dergisi*, 6(2), 152-159. https://doi.org/10.24180/ijaws.709110

Gjamovski, V., & Kiprijanovski, M. (2011). Influence of nine dwarfing apple rootstocks on vigour and productivity of apple cultivar 'Granny Smith', *Scientia Horticulturae*, 129(4), 742-746. https://doi.org/10.1016/j.scienta.2011.05.032

González-Aguilar, G., Robles-Sánchez, R. M., Martínez-Téllez, M. A., Olivas, G. I., Alvarez-Parrilla, E., & De La Rosa, L. A. (2008). Bioactive compounds in fruits: Health benefits and effect of storage conditions. *Stewart Postharvest Review*, 4(3), 1-10. https://doi.org/10.2212/spr.2008.3.8

Kammerer, D. R., Saleh, Z. S., Carle, R., & Stanley, R. A. (2007). Adsorptive recovery of phenolic compounds from apple juice. *European Food Research and Technology*, 224(5), 605-613. https://doi.org/10.1007/s00217-006-0346-5

Marinova, D., Ribarova, F., & Atanassova, M. (2005). Total phenolics and total flavonoids in Bulgarian fruits and vegetables. *Journal of the University of Chemical Technology and Metallurgy*, 40(3), 255-260.

McGuire, R. G. (1992). Reporting of objective color measurements. *HortScience*, 27(12), 1254-1255. https://doi.org/10.21273/HORTSCI.27.12.1254

Ozkan, Y., Küçüker, E., Çekiç, Ç., Mehder, B., & Çakır, A. (2009). Slender spindle (İnce iğ) sistemi uygulanmış bazı elma çeşitlerinde ağaç ve meyve özellikleri. *Tarım Bilimleri Araştırma Dergisi*, 2(2), 137-143.

Ozmen, Z. S., & Çekiç, Ç. (2018). Tokat Yöresinde Yetişen Yerel Elma Genotiplerinde Pomolojik Özelliklerin Tespiti. *Gaziosmanpaşa Üniversitesi Ziraat Fakültesi Dergisi*, 35(Ek Sayı), 102-107. https://doi.org/10.13002/jafag4516

Ozongun, Ş., Dolunay, E., Öztürk, G., & Pektaş, M. (2014). Eğirdir (Isparta) şartlarında bazı elma çeşitlerinin performansları. *Meyve Bilimi*, 1(2), 21-29.

Ozongun, Ş., Dolunay, E., Pektaş, M., Öztürk, G., Çalhan, Ö., & Atay, E. (2016). Farklı klon anaçları üzerinde bazı elma çeşitlerinin verim ve kalite değişimleri. *Ege Üniversitesi Ziraat Fakültesi Dergisi*, 53(1), 35-42. https://doi.org/10.20289/zfdergi.179870

Ozturk, A., & Ozturk, B. (2016). Samsun ekolojisinde yetiştirilen standart bazı elma çeşitlerinin fenolojik ve pomolojik özelliklerinin belirlenmesi. *Anadolu Tarım Bilimleri Dergisi*, 31(1), 1-8. https://doi.org/10.7161/anajas.2016.31.1.1-8

Oztürk, B., Uzun, S., Bektaş, E., Yarılgaç, T., Karakaya, M., Karakaya, O., Gün, S., & Turga, E. (2016). Determination of yield and quality characteristics of some apple cultivars grafted on M9 rootstock under ecological conditions of Ordu province. *Bahçe*, 45: 492-497.

Soylu, A., Ertürk, Ü., Mert, C., & Öztürk, Ö. (2003). MM 106 anacı üzerine aşılı elma çeşitlerinin Görükle koşullarındaki verim ve kalite özelliklerinin incelenmesi-II. *Uludağ Üniversitesi Ziraat Fakültesi Dergisi*, 17(2), 57-65.

Sensoy, M., & Bostan, S. Z. (2019). Ulubey ilçesinde (Ordu) MM 106 ve M 9 anaçları üzerindeki 'Granny Smith' elma çeşidinin ilk yıllar verim ve pomolojik özellikleri. *Akademik Ziraat Dergisi*, 8(1), 9-12. https://doi.org/10.29278/azd.592940

Turan, S., & Karlıdag, H. (2022). Bazı elma çeşitlerinin Malatya ili Battalgazi ilçesi ova koşullarında performanslarının belirlenmesi. *Harran Tarım ve Gıda Bilimleri Dergisi*, 26(2), 169-180. https://doi.org/10.29050/harranziraat.1078373

Uzun, S., & Ozturk, B. (2020). Effects of aminoethoxyvinylglycine and modified atmosphere packaging treatments on the color characteristics and antioxidant activity of kiwifruit during cold storage and shelf life. *Journal of Postharvest Technology*, 8(4), 9-17.

Yue, T., Bai, X., Zhang, H., & Yuan, Y. (2012). Fractionation and anti-inflammatory effects of polyphenol-enriched extracts from apple pomace. Bangladesh Journal of Pharmacology, 7(1), 28-32. https://doi.org/10.3329/bjp.v7i1.10194