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Determination Phenologial and Fruit Quality Performances of Some Standard Apple Varieties Grown in the Ereğli (Konya) Region

Ereğli (Konya) Bölgesinde Yetiştirilen Bazı Standart Elma Çeşitlerinin Fenolojik ve Meyve Kalite Parametrelerinin Belirlenmesi

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DETERMINATION PHENOLOGIAL AND FRUIT QUALITY PERFORMANCES OF SOME STANDARD APPLE VARIETIES GROWN IN THE EREĞLI (KONYA) REGION

ABSTRACT

This study was conducted in 2023-2024 growing periods to determine the performance of some standard apple varieties grown under the ecological conditions of the Ereğli district in Konya province. The study evaluated the phenological, physical, and pomological characteristics of Golden Delicious, Starkrimson Delicious, Granny Smith, and Fuji apple varieties. According to the results, bud swelling occurred between March 29 and April 13, bud breaking between April 4 and 20, the beginning of flowering between April 9 and 18, full blooming between April 16 and 30, the end of flowering between April 23 and May 7, harvest between September 6 and October 25, and leaf fall between December 6 and 14. The fruit weights ranged from 145 g (Golden Delicious) to 196 g (Fuji), and fruit firmness ranged from 5.44 kg cm^{-2} (Golden Delicious) to 7.10 kg cm^{-2} (Starking Delicious). Fruit peel color values varied, with L* ranging from 38.42 (Starking Delicious) to 75.81 (Golden Delicious), a* from -5.52 (Golden Delicious) to 27.98 (Starking Delicious), and b* from 11.96 (Starking Delicious) to 47.56 (Golden Delicious). The soluble solid content (SSC) ranged from 9.25% (Golden Delicious) to 11.51% (Fuji), pH values from 3.32 (Granny Smith) to 4.15 (Starking Delicious), and titratable acidity from 0.38% (Starking Delicious) to 0.93% (Fuji). The findings revealed significant differences among the studied cultivars in terms of adaptation to regional conditions, as well as yield and quality characteristics.

Keywords: Apple, Characteristic, Ereğli, Quality, Pomology.

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EREĞLİ (KONYA) BÖLGESİNDE YETİŞTİRİLEN BAZI STANDART ELMA ÇEŞİTLERİNİN FENOLOJİK VE MEYVE KALİTE PARAMETRELERİNİN BELİRLENMESİ

ÖZ

Bu çalışma, Konya ili Ereğli yöresi ekolojik şartlarında yetiştirilen bazı standart elma çeşitlerinin performanslarının belirlenmesi amacıyla 2023-2024 yıllarınında yürütülmüştür. Çalışmada; Golden Delicious, Starkrimson Delicious, Granny Smith ve Fuji elma çeşitlerinin fenolojik, fiziksel ve pomolojik özellikleri çalışılmıştır. Çalışma sonuçlarına göre; tomurcuk kabarması 29 Mart- 13 Nisan, tomurcuk patlaması 4-20 Nisan, çiçeklenme başlangıcı 9-18 Nisan, tam çiçeklenme

16-30 Nisan, çiçeklenme sonu 23 Nisan-7 Mayıs, hasat zamanı 6 Eylül-25 Ekim, yaprak dökümü 6-14 Aralık tarihleri arasında gerçekleşmiştir. Çeşitlerin ortalama meyve ağırlığı 145 g (Golden Delicious) – 196 g (Fuji), meyve eti sertliği 5.44 kg cm-2 (Golden Delicious) – 7.10 kg cm-2 (Starking Delicious), meyve kabuk renk değerleri L değeri 38.42 (Starking Delicious) – 75.81 (Golden Delicious), a değeri Golden Delicious (-5.52)- Starking Delicious (27.98), b değeri Starking Delicious (11.96)- Golden Delicious (47.56) olarak bulunmuştur. Çeşitlerin SÇKM değeri %9.25 (Golden Delicious) -% 11.51 (Fuji), pH değeri 3.32 (Granny Smith) -4.15 (Starking Delicious), titre edilebilir asit miktarı %0.38 (Starking Delicious) - %0.93 (Fuji) arasında değişim göstermiştir. Elde edilen bulgular, incelenen çeşitlerin bölge koşullarına adaptasyon düzeyleri, verim ve kalite özellikleri açısından önemli farklılıklar gösterdiğini ortaya koymuştur.

Anahtar Kelimeler: Elma, Ereğli, Kalite, Özelllik, Pomoloji.

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1. INTRODUCTION

Apple (*Malus spp*.), a member of the Rosaceae family, is cultivated in temperate climate regions across all continents except Antarctica. Owing to its wide varietal range and rootstock diversity, it can readily adapt to diverse climatic and soil conditions. Türkiye, one of the genetic centers of apples, holds a significant position in global apple production (Aslantaş, 2014). The species is believed to have originated in the South Caucasus region, which includes Anatolia. Favorable ecological conditions and varietal diversity have enabled apple cultivation to spread across almost all parts of Türkiye, with the most suitable production areas concentrated in Northern Anatolia particularly in the transition zones between the Black Sea coastal region and the plateaus of Central and Eastern Anatolia, as well as the Lakes Region in the south in recent years. As of 2024, Türkiye's total apple production reached approximately 4.21 million tons (Anonymous, 2025), with Konya province contributing 198.483 tons, underscoring its importance in national production. Apple cultivation is widespread in regions such as Niğde, Konya, Kocaeli, Amasya, Tokat, Isparta, and Denizli (Özçağıran et al., 2004;Arıkan 2020). Apples appeal to a broad range of consumers worldwide due to their taste, nutritional value, and affordability, which has enabled them to secure a large share in international fruit trade markets (Bayav, 2007;O'Rourke, 2021).

Beyond its agricultural significance, the apple is among the most economically valuable fruit crops globally, with strong export potential and high industrial demand. In addition to fresh consumption, it is widely processed into juice, cider, vinegar, dried products, jams, and various confectionery and bakery items. Apples are nutritionally rich, containing dietary fiber, vitamin C, potassium, magnesium,

and a wide spectrum of polyphenolic compounds such as quercetin, catechins, chlorogenic acid, and anthocyanins (Hyson, 2011). These bioactive compounds are linked to numerous health-promoting effects, including antioxidant, anti-inflammatory, cardioprotective, and anti-obesity activities, and they may reduce the risk of chronic diseases such as type 2 diabetes, cardiovascular disorders, and certain cancers (Boyer & Liu, 2004; Bai et al., 2024). This combination of economic, industrial, nutritional, and functional value underscores the importance of apple cultivation not only for agricultural sustainability but also for public health and the functional food industry.

In agricultural production, the final form and composition of a product are cumulatively influenced by ecological factors such as light, humidity, temperature, soil texture, and soil fauna, and the responses of species and cultivars to these factors vary (Li et al., 2012; Tiwari and Cummins, 2013). Apple, with its low ecological selectivity and high adaptability, exhibits a wide diversity of summer, autumn, and winter cultivars across Türkiye. However, only a limited number of these cultivars have gained commercial importance in terms of yield, quality, suitability for cultivation, and storage potential (Kaşka, 1997; Özçağıran et al., 2005; Eskimez et al. 2020). One of the most critical factors in successful fruit production is the correct selection of varieties. Although Türkiye possesses a rich apple germplasm, the production of standard, export-oriented varieties remains below the desired level. Breeding programs have produced new varieties each year with improved consumer appeal, disease and pest resistance, storability, and superior quality (Balta and Kaya, 2007). The performance of apple trees can vary depending on environmental conditions, and in areas prone to late spring frosts, apples serve as an important alternative fruit crop. Therefore, regional studies on the phenological (flowering time, harvest date) and pomological (fruit weight, shape, chemical composition) traits of different varieties are essential (Özbek, 1978;Şenyurt et al. 2015;Eskimez et al. 2020). In recent years, numerous studies have focused on evaluating apple varieties in terms of yield, quality parameters, and storage performance under different ecological conditions. However, there is still a limited number of region-specific studies that simultaneously assess both phenological and pomological traits of standard apple cultivars under the unique ecological conditions of the Ereğli district, Konya province. This gap is particularly important considering the increasing impacts of climate change on fruit development physiology, harvest timing, and quality stability. The present study aims to fill this knowledge gap by providing comprehensive and up to date data on the phenological and pomological characteristics of prominent apple varieties cultivated in this region. The findings will not only guide local producers in selecting suitable cultivars but also contribute to the development of region-specific cultivation strategies, ensuring both economic efficiency and sustainability in apple production.

2. MATERIALS AND METHODS

2.1. Material

This study was conducted in the orchard of a producer named Şeref DOĞAN, located in Çakmak village, Ereğli district of Konya province. The plant materials used in the experiment included 15-year-old apple cultivars Golden Delicious, Starking Delicious, Granny Smith, Fuji grafted onto MM 106 rootstock and pruned Central Leader system. In the orchard where the research was carried out, technical and cultural practices were regularly performed.

The annual mean temperature in the research area was approximately 16.0 °C, with 2024 being slightly milder compared to 2023 (20.3/7.9 °C). The average relative humidity was 47.7%, and the total annual precipitation was about 327 mm. The warmest month was July (28.4°C), while the coldest month was December (4.1°C). The highest precipitation occurred in November–December (61–64 mm). During the summer months (June–August), elevated temperatures (28°C) and low humidity levels (26–33%) resulted in increased evaporation and evapotranspiration. (Figure 1;Figure 2).

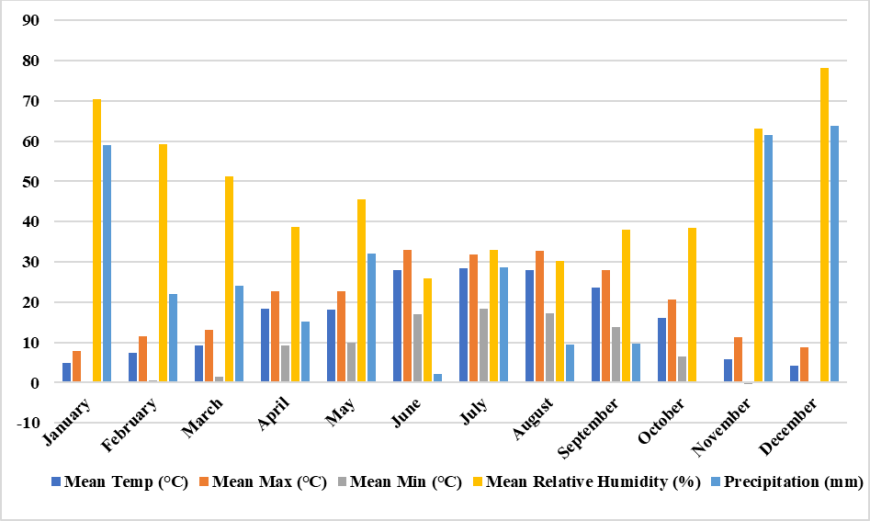

Figure 1. Climate data for Ereğli district, Konya province, for the year 2024

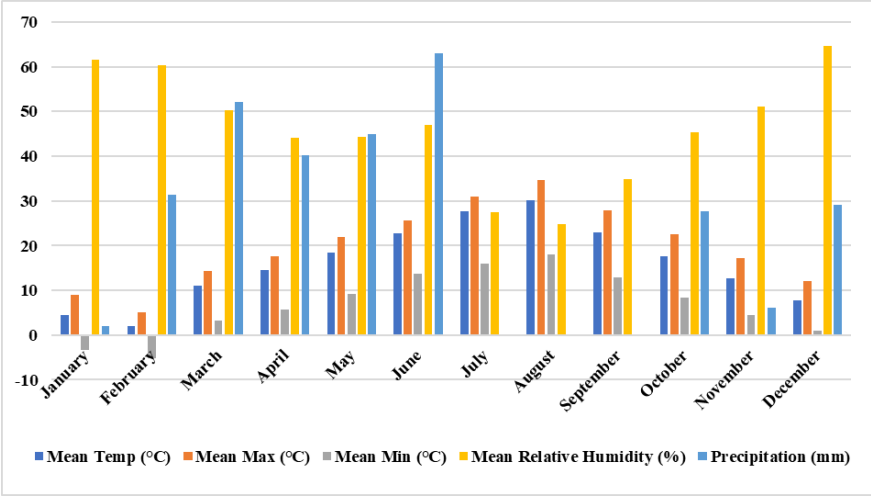

Figure 2. Climate data for Ereğli district, Konya province, for the year 2023

2.2. Method

2.2.1. Phenological Characteristics

In the study, the period from full bloom to harvest was determined based on fruit ripening criteria and the phenological characteristics of the cultivars, and this parameter was used to compare their maturation periods. The dates of bud break, bud burst, first flowering, full bloom, end of flowering, and harvest were recorded following the method described by Eskimez et al. (2020). Based on these records, the number of days from full bloom to harvest was calculated.

2.2.2. Pomological Characteristics

Fruit Dimensions

After removing the largest and smallest fruits, randomly selected fruits from each variety were weighed using a precision balance with an accuracy of 0.01 g to determine fruit weight (g) and seed weight. (Çulha, 2010).

Fruit length (mm), fruit width (mm), fruit skin thickness (mm), fruit stalk length and thickness, fruit stalk cavity width and depth, and fruit calyx cavity width and depth were measured using a digital caliper with an accuracy of 0.01 mm, and their average values were determined (Balta et al. 2015;Çöçen et al. 2019; Eskimez, et al. 2020).

2.2.3. Seed Dimensions

Seed length (mm), seed width (mm), seed thickness (mm), seed cavity length(mm) and seed cavity width(mm) were measured with a digital caliper with an accuracy of 0.01 mm, and the average values were recorded.

The fruit shape index was calculated by dividing the fruit length by the fruit diameter (Balta et al. 2014; Eskimez, et al. 2020).

The number of fully developed seeds was determined by counting the seeds in 10 randomly selected fruits, and the average value was recorded.

2.2.4. Color Measurement

For color determination, five fruits randomly selected from 10 replicates representing the varieties were measured for skin ground color (L*, a*, b*) using a color measurement device (Minolta Co., model CR-400, Tokyo, Japan). Measurements were taken from the sun-exposed side and the calyx end of the fruits. The fruit color was recorded in terms of L*, a*, and b* values. Using the obtained a* and b* values, *Chroma (C)**, which determines color saturation and vibrancy, and Hue angle (ho), which represents the basic color components (red, yellow, blue, and green), (Eskimez, et al. 2020), were calculated as follows:

$C^* = (a^{*2}+b^{*2})1/2$, $ho = \tan\text{-}1\ (b^*/a^*)$

2.2.5. Soluble Solid Content (SSC)

The SSC of the juice, representing the varieties, was measured using a digital refractometer (Atago, Japan), and the results were recorded as % SSC in °Brix (Uzun et al. 2015; İkinci & Bolat, 2016; Eskimez, et al. 2020).

2.2.6 Titratable Acidity (TA)

For titratable acidity determination, 1 ml of fruit juice was titrated with 0.1 N NaOH solution until the pH reached 8.1, and acidity was expressed as a percentage of malic acid (Cemeroğlu, 2007 Eskimez, et al. 2020).

2.2.7 pH Determination

A 10 ml sample of fruit juice from each variety was analyzed by immersing the electrode tip of a digital pH meter into the juice. The value was recorded once the pH meter stabilized (Eskimez, et al. 2020).

2.2.8. Statistical Analyses

The study was designed according to a randomized complete block design with ten replications. For pomological characteristics, measurements were taken on twenty fruits collected from four sides of the tree in each replication (10 trees and 200 fruits for each cultivar). For phytochemical analyses, the remaining fruits from each replication were converted into juice using a fruit juicer and used for analyses. Descriptive statistics, including means and standard errors, were calculated for the studied characteristics, to determine whether there were significant differences between the means of different varieties, ANOVA (Analysis of Variance) was conducted. Following the variance analysis, Duncan's multiple comparison test was used to identify significantly different varieties. The significance level was set at 5%, and all statistical analyses were conducted using the IBM SPSS Statistics 22 software package (Düzgüneş et al. 1987).

3. RESULTS AND DISCUSSION

3.1. Phenological Observations

The most important factor determining the direction of plant production in any region is the suitability of ecological conditions. In this context, studies on the adaptation of species and their cultivars to specific regions are of great importance for ensuring sustainable, productive, and high-quality agricultural production. Among the cultivars of deciduous fruit species, the formation physiology of the reproductive organs is similar; however, the fruit development after fertilization (development physiology) differs. This situation causes the differences in harvest dates to be greater than the differences in flowering dates.

Phenological observations conducted in 2023 and 2024 are presented in Table 1. Due to the above-average winter temperatures in 2023 in the study region, the phenological cycles of apple trees occurred 6–7 days earlier compared to 2024. This shows that the total number of growing degree hours in 2023 is higher than in 2024.The observations indicated that Starking Delicious was the earliest maturing variety in all phenological stages, followed by Granny Smith. However, in 2023, all phenological stages occurred 5–7 days earlier. These shifts in phenological stages, observed across both varieties and years, are as follows:

In 2023, the observations indicated that Starking Delicious had the earliest phenological stages, followed by Granny Smith. The dates of bud swelling, bud breaking, flowering start, full blooming, end of flowering and harvest for Starking Delicious were 29-30 March, 4-5 April, 9-11 April, 16-17 April, 23-25 April and 12 September, respectively. The number of days from full bloom to harvest was 149.

But the shortest period from full bloom to harvest was 141 in the Golden Delicious. This is due to the fact that higher average temperatures accelerate developmental physiology. Fuji had the latest phenological stages. The dates of bud swelling, bud breaking, flowering start, full blooming, end of flowering and harvest for Fuji were 6-7 April, 12-14 April, 17-19 April, 22-24 April, 29-30 April and 17 October, respectively. The number of days from full bloom to harvest was 178 .

These findings suggest that climatic conditions significantly influence the phenological development of apple varieties. The earlier onset of developmental stages highlights the potential impact of climate variability on apple production timing. (Eskimez et al. 2020: Chitu and Paltineanu, 2020).

In 2024, Starking Delicious had the earliest phenological stages, followed by Granny Smith. The dates of bud swelling, bud breaking, flowering start, full blooming, end of flowering and harvest for Starking Delicious were 6-7 April, 10-12 April, 15-17 April, 22-23 April, 29-30 April and 18 September, respectively. The number of days from full bloom to harvest was 155. Fuji had the latest phenological stages. The dates of bud swelling, bud breaking, flowering start, full blooming, end of flowering and harvest for Fuji were 12-13 April, 19-20 April, 25-26 April, 29-30 April, 6-7 May and 25 October, respectively. The number of days from full bloom to harvest was 185'

These findings provide crucial references for determining the phenological stages of different apple varieties and for agricultural planning. Particularly, the consistency in phenological responses of varieties across years offers valuable insights into the impact of regional climatic conditions on apple production. Ceylan (2008) conducted a study in Niğde's ecological conditions in 2006-2007, thoroughly examining the phenological characteristics of apple varieties. Flowering duration was found to be 10-11 days for all varieties. The study observed that bud swelling began two weeks earlier in 2006 compared to 2007, with the Granny Smith starting from March 27 to April 13, and Fuji from March 27 to April 14. The study also noted that the full blooming-to-harvest date in 2006 ranged from 122 to 164 days, while in 2007, it was between 118 and 156 days, with harvest occurring one week earlier in 2006. Similarly, Seymen and Polat (2015) in their research at the Eğirdir Fruit Research Station during 2012-2013, observed a 20-25 day advance in all phenological stages, such as bud swelling, bud breaking, first flowering, full blooming, the end of flowering, and leaf fall, compared to the previous year. Yarılgaç et al. (2009) found similar trends in their study of 15 local apple types in Ordu between 2007-2008, observing differences of 5-8 days for flowering start, 4-9 days for full blooming, and 3-10 days for the end of flowering between the two years. In a study conducted in the Upper Coruh Valley in 2000-2001, Karlıdağ and Eşitken (2006) found that the full bloom-to-harvest date for Amasya apple variety was recorded as 151 and 150 days in 2000 and 2001, respectively. Turan and

Karlıdağ (2022), during their study on various apple varieties in Malatya in 2018-2019, found the following phenological stages: bud swelling from March 13-27, bud breaking from March 20-April 1, flowering start from March 31-April 18, full blooming from April 5-24, the end of flowering from April 11-May 1, harvest time from September 16-November 8, and leaf fall from December 4-15. These findings align with similar studies on the same varieties. The data collected from these various studies are consistent and show that climate conditions significantly impact the timing of phenological stages. The time from full blooming to harvest stands out as an important criterion for determining harvest times, and the study results reinforce the idea that climatic differences influence this critical period. These findings mirror other global studies on the adaptation and selection of fruit varieties, such as almond, where phenological differences are also linked to genetic factors, altitude, soil, ecological conditions, and environmental factors, all of which have been highlighted by previous researchers (Dokuzoğuz and Gülcan 1973; Aslantaş 1993; Balta 2001; Dicenta et al. 2010; Acar et al. 2018). Studies emphasize the significant impact of these factors on the phenological stages of varieties. However, the Golden Delicious is a generalist pollinator. No problems with pollination or fertilization were encountered due to its varietal composition.

Table 1. Phenological observation dates of apple varieties for 2023 – 2024

Varieties	Years	B.S (day/month)	B.B (day/month)	F.S (day/month)	F.B (day/month)	T.E.F (day/month)	H.D (day/month)	T.F.B.H (day)
Golden Delicious	2023	4-5 April	9-10 April	13-15 April	21-23 April	29-30 April	9 September	141
	2024	10-12 April	15-16 April	19-20 April	26-28 April	3-4 Mayıs	15 September	148
Granny Smith	2023	1-2 April	6-7 April	12-14 April	18-20 April	26-28 April	18 September	151
	2024	8-10 April	13-15 April	20-21 April	26-27 April	1-2 Mayıs	25 September	157
Starking Delicious	2023	29-30 March	4-5 April	9-11 April	16-17 April	23-25 April	12 September	149
	2024	6-7 April	10-12 April	15-17 April	22-23 April	29-30 April	18 September	155
Fuji	2023	6-7 April	12-14 April	17-19 April	22-24 April	29-30 April	17 October	178
	2024	12-13 April	19-20 April	25-26 April	29-30 April	6-7 May	25 October	185

B.S: Bud Swelling,

B.B: Bud Breaking,

F.S: Flowering Start.

F.B: Full Blooming

T.E.F: The End of Flowering,

H.D: Harvest Date

T.F.B.H: Time from Full Bloom to Harvest

3.2. Physical and Chemical Properties

The average physical measurement values of the apple varieties studied for the years 2023 and 2024 are presented in Table 2. The analysis showed statistically significant differences ($p<0.05$) among the apple varieties in terms of pomological and chemical properties.

The measurements on apple varieties showed that fruit weight ranged from 145 g in Golden Delicious to 196 g in Fuji. Fruit height varied between 60.79 mm in Granny Smith and 64.68 mm in Golden Delicious, while fruit width ranged from 65.13 mm in Golden Delicious to 74.97 mm in Fuji. The fruit shape index was lowest in Fuji (0.84) and highest in Golden Delicious (0.97). Seed count ranged from 5.25 in Golden Delicious to 11.25 in Fuji.

Table 2. Average pomological analysis results for 2023-2024

Varieties	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Fruit shape index (mm)	Fruit stalk length (mm)	Fruit stalk thickness (mm)
Golden Delicious	145±10.43b	64.68±2.86a	65.13±1.43b	0.97±0.04a	32.29±3.10a	2.23±0.13b
Granny Smith	157.75±10.35b	60.79±1.75c	67.83±4.02b	0.89±0.01b	22.86±1.44b	2.33±0.20b
Starking Delicious	169±10.82b	65.46±4.40a	4.54±0.88a	0.88±0.03b	30.36±4.25a	3.00±0.35a
Fuji	196±13.41a	62.02±1.34b	74.97±2.25a	0.84±0.02b	26.35±2.63b	2.66±0.17ab
LSD	0.05	0.04	0.01	0.02	0.01	0.02

Mean values in the column followed by the same letter(s) are not significantly different at ($p<0.05$)

In adaptation studies for table consumption, the characterization of traits that shape consumer preferences is of great importance. Özrenk et al. (2011) determined that the fruit shape index of local apple varieties grown in Çatak and Tatvan regions ranged between 0.9-1.1. Similarly, Granger et al. (1997) reported a fruit shape index of 0.95-1 for the Primavere, while Kaya and Balta (2007) found a range of 0.80-0.90 in their study conducted in Gevaş, Van. Fruit firmness is a crucial factor affecting both harvest time and storage duration. Turan and Karlıdağ (2022), in their study conducted in Malatya, found that the fruit weight of apple varieties ranged from 131.17 g (Pink Lady) to 160.7 g (Granny Smith), while fruit firmness varied between 4.5 kg cm^{-2} (Golden Delicious) and 6.72 kg cm^{-2} (Granny Smith). Bolat et al. (2019), in a study conducted in Osmaniye, determined that the Fuji had an average fruit weight of 212.80 g, fruit length of 65.40 mm, fruit width of 79.30 mm, and fruit firmness of 8.20 kg cm^{-2}. Arıkan et al. (2015), in their study in the Konya Plain, measured the fruit weight of Fuji at 142.33 g and Golden Delicious at 164.76 g; fruit width at 68.43 mm (Fuji) and 72.00 mm (Golden Delicious); fruit height at 58.59 mm (Fuji) and 64.95 mm (Golden Delicious), and fruit firmness between 4.96 kg cm^{-2} (Fuji) and 4.67 kg cm^{-2} (Golden Delicious). Şenyurt et al.

(2015), in their study conducted in Gümüşhane, observed that the fruit weight of local apple varieties ranged from 80.70 g to 195.61 g, fruit length from 52.09 mm to 66.29 mm, fruit width from 57.27 mm to 80.77 mm, and fruit firmness between 6.27 kg/cm² and 9.39 kg/cm². Öztürk and Öztürk (2016), in their research conducted in Samsun, determined that the fruit weight of Golden Delicious ranged from 122.2 g to 173.9 g (Starkrimson Delicious); fruit width varied from 64.83 mm (Golden Delicious) to 74.27 mm (Granny Smith); fruit height ranged from 59.16 mm (Golden Delicious) to 62.12 mm (Granny Smith), and fruit firmness was found to be 66.40 N/mm, 78.30 N/mm, and 72.10 N/mm for Golden Delicious, Granny Smith, and Starkrimson Delicious, respectively.

Studies highlight the significant influence of growing ecology (climate, soil properties) and genetic diversity on the phenological and pomological characteristics of apples. The higher fruit weight and firmness of Fuji apples in Osmaniye compared to other regions can be attributed to the warmer climatic conditions of the area. The variation in fruit firmness and weight in Samsun is associated with the region's moderately humid and temperate climate conditions. Studies conducted in Konya, Malatya, and Gümüşhane emphasize the impact of different ecological conditions on fruit quality and physical properties. These findings underline the effects of ecological factors and variety on the physical and chemical properties of apples. In particular, fruit firmness plays a critical role in determining storage duration and market quality.

The average physical measurement values of the selected apple varieties for 2023 and 2024 are presented in Tables 3 and 4. The study found variations in several fruit and seed characteristics:

The measurements on apple varieties also indicated that fruit stalk length ranged from 22.86 mm in Granny Smith to 32.29 mm in Golden Delicious, while fruit stalk thickness varied between 2.23 mm in Golden Delicious and 3.00 mm in Starkrimson Delicious. Fruit stalk cavity width was smallest in Fuji (27.43 mm) and largest in Starkrimson Delicious (30.39 mm), whereas fruit stalk cavity depth ranged from 15.52 mm in Granny Smith to 22.26 mm in Fuji. The fruit calyx cavity width ranged from 20.47 mm in Golden Delicious to 27.57 mm in Fuji, and calyx cavity depth varied between 11.76 mm in Granny Smith and 19.53 mm in Fuji. Peel thickness was lowest in Starkrimson Delicious (1.09 mm) and highest in Granny Smith (1.46 mm).

Regarding seed-related characteristics, seed weight ranged from 0.06 g (Golden Delicious – Granny Smith) to 0.07 g (Starkrimson Delicious – Fuji). Seed length varied between 5.17 mm in Starkrimson Delicious and 9.17 mm in Fuji, seed width ranged from 2.71 mm in Starkrimson Delicious to 5.21 mm in Granny Smith, and seed thickness was lowest in Starkrimson Delicious (1.83 mm) and highest in

Granny Smith (2.96 mm). Core length ranged from 25.31 mm in Fuji to 32.53 mm in Granny Smith, while core width varied between 23.54 mm in Golden Delicious and 27.57 mm in Granny Smith.

Table 3. Average pomological analysis results for 2023-2024

Varieties	Fruit stalk cavity width (mm)	Fruit stalk cavity depth (mm)	Fruit calyx cavity width (mm)	Fruit calyx cavity depth (mm)	Seed count	Peel thickness (mm)
Golden Delicious	27.43±0.68b	18.24±0.18ab	20.47±1.10b	14.92±1.89ab	5.25±1.29c	1.43±0.06a
Granny Smith	27.58±1.07b	15.52±1.06b	25.11±0.36a	11.76±0.85b	8.00±0.00b	1.46±0.04a
Starking Delicious	30.39±0.95a	21.04±2.34a	24.90±1.96a	18.80±5.52a	6.00±0.70c	1.09±0.04b
Fuji	30.28±1.62a	22.26±3.69a	27.57±1.78a	19.53±1.86a	11.25±0.82a	1.17±0.10b
LSD	0.02	0.01	0.01	0.03	ns	ns

Mean values in the column followed by the same letter(s) are not significantly different at ($p<0.05$). ns: No significant

Table 4. Average pomological analysis results for 2023-2024

Varieties	Seed length (mm)	Seed width (mm)	Seed thickness (mm)	Seed weight (g)	Seed cavity length (mm)	Seed cavity width (mm)
Golden Delicious	8.24±0.51a	4.84±0.12a	2.76±0.12a	0.06±0.00b	27.28±0.93b	24.35±0.62ab
Granny Smith	8.19±0.67a	5.21±0.38a	2.96±0.10a	0.06±0.00b	32.53±4.65a	27.57±2.67a
Starking Delicious	5.17±0.31b	2.71±0.20b	1.83±0.07b	0.07±0.00a	26.20±1.70b	23.54±2.32b
Fuji	9.17±0.27a	4.81±0.19a	2.95±0.07a	0.07±0.00a	25.31±1.25b	26.08±1.01ab
LSD	ns	ns	ns	0.02	0.02	ns

Mean values in the column followed by the same letter(s) are not significantly different at ($p<0.05$. ns: No significant

Compared to previous studies, our study: Şenyurt et al. (2015), in their study on standard and local apple varieties in Gümüşhane (2011-2012), found fruit shape indices of 0.85-0.93 mm, pedicel lengths of 18.25-31.03 mm, pedicel thicknesses of 1.65-2.40 mm, pedicel cavity widths of 16.37-25.48 mm, and pedicel cavity depths of 8.18-14.59 mm. Their findings also reported calyx cavity widths of 16.37-25.48 mm, calyx cavity depths of 7.46-13.90 mm, core lengths of 19.46-26.08 mm, core widths of 18.09-27.16 mm, and seed weights between 0.061-0.060 g. Özrenk et al. (2011), in their study on local apple varieties from Çatak and Tatvan, reported pedicel lengths of 7.9-32.2 mm, pedicel thicknesses of 1.3-2.9 mm, pedicel cavity widths of 6.3-14.3 mm, pedicel cavity depths of 3.1-9.1 mm, calyx cavity widths of 7.8-14.5 mm, and calyx cavity depths of 1-6 mm. Their study also found peel thickness ranging from 0.3 to 0.5 mm, seed weights of 0.3-0.8 g, seed lengths of 6.5-9.1 mm, seed widths of 3.3-4.9 mm, core lengths of 12.9-22.5 mm, and core widths of 6.3-10.6 mm. These findings emphasize the impact of genetic structure and cultivation ecology on the morphological characteristics of apple varieties. Additionally, significant differences in fruit and seed properties were observed,

which could influence commercial apple production, harvest, and storage processes. The average chemical analysis values of the selected apple varieties for 2023 and 2024 are presented in Table 5. The study identified the following chemical parameters for the apple varieties: pH values ranged from 3.32 (Granny Smith) to 3.83 (Fuji). Soluble solid content (SSC) ranged from 9.25% (Golden Delicious) to 11.51% (Fuji). Titratable acidity ranged from 0.38% (Starkrimson Delicious) to 0.71% (Granny Smith).

Table 5. Some average pomological analysis results for 2023-2024

Varieties	Fruit flesh hardness (kg cm^{-2})	pH	SSC (%)	Titratable acidity (%)
Granny Smith	6.30 ±0.22b	3.32±0.06c	9.85±0.25b	0.71±0.08a
Golden Delicious	5.44±0.16c	3.73±0.06b	9.25±0.09c	0.69±0.53a
Fuji	6.98±0.10b	3.83±0.08b	11.51±0.08a	0.63±0.04b
Starking Delicious	7.10±0.32a	4.15±0.08a	9.97±0.16b	0.38±0.26c
LSD	ns	ns	ns	ns

Mean values in the column followed by the same letter(s) are not significantly different at ($p<0.05$). ns: No significant

In study, SSC, pH, and titratable acidity (TA) values among the apple cultivars were found to be decisive for both consumer preferences and postharvest storage. Fuji, with its high SSC and balanced TA content, stood out for its sweeter and more aromatic profile, making it highly favorable for fresh consumption. Golden Delicious, with moderate SSC and acidity, appealed to a wide range of consumers, offering a balanced sweet sour taste that makes it suitable for both fresh consumption and processing. Granny Smith was characterized by high acidity and low pH, preferred by consumers who favor a sour taste, and showed strong potential for industrial use, particularly in juice and pie production. Starking Delicious, on the other hand, exhibited relatively lower acidity and medium SSC values, resulting in a milder flavor profile, though it showed a faster change in sugar acid balance during storage. During the postharvest period, while SSC remained largely stable, TA decreased and pH increased, altering the taste balance differently among cultivars. Notably, high acidity cultivars such as Granny Smith preserved their flavor longer during storage, whereas lower acidity cultivars like Starking and Golden tended to lose their flavor more quickly. These findings highlight that the sugar acid balance directly affects not only consumer acceptance but also storage performance. Turan and Karlıdağ (2022), in their study on apple varieties in Battalgazi (Malatya) under local ecological conditions during 2018-2019, reported SSC values between 12.60% (Granny Smith) and 16.83% (Fuji), with pH values ranging from 3.41 (Fuji) to 4.48 (Pink Lady). Arıkan et al. (2015), in their study conducted in the Konya plain, found pH values ranging from 3.43 (Jersey Mac) to 4.30 (Red Chief), titratable acidity values from 0.31 (Red Chief) to 0.73 (Jersey Mac), and SSC values between 10.21% (Jersey Mac) and 13.29% (Jonagold). Şenyurt et al. (2015), in their study in Gümüşhane (2011-2012), found soluble solid content (SSC) values

between 11.50% and 15.25%, pH values from 3.53 to 4.87, and titratable acidity between 0.20% and 1.24%. Balta et al. (2014), in their study in Kumru (Ordu), identified fruit firmness between 6.94 and 12.64 pounds, SÇKM values from 9.40% to 13.60%, pH values from 2.83 to 4.11, and titratable acidity values from 0.22% to 2.01%.

The pH values of the varieties in this study ranged generally from 3 to 4, reflecting the acidic nature of apples and the variety-dependent differences. Soluble Solid Content (SSC): This parameter, reflecting the sugar content, was found to be high in varieties such as Fuji and Granny Smith. Titratable Acidity: The acidity, which influences taste and aroma, was higher in Fuji and Granny Smith varieties. Sugar/Acid Ratio: This ratio, which expresses the balance between sweetness and acidity, is important depending on the intended use of the variety (e.g., fresh consumption or industrial use). These findings emphasize the importance of chemical parameters in apple quality and consumer preferences in apple cultivation. Additionally, the study clearly demonstrates the significant impact of ecological conditions on the chemical composition of apples.

Apple varieties' fruit skin color parameters are directly related to genetic characteristics and growing conditions. The color values obtained in the research and the data in the literature can be summarized as follows. The L* color values of the examined apple varieties ranged between 38.42 (Starkrimson Delicious) and 75.81 (Golden Delicious). In both years of the research, the varieties with the brightest (lightest) fruit skin color were Golden Delicious and Granny Smith, while the variety with the dullest (darkest) fruit skin color was Starkrimson Delicious. On the other hand, the a* value of the apple varieties ranged from -5.52 (Golden Delicious) to 27.98 (Starking Delicious), the b* value ranged from 11.96 (Starkrimson Delicious) to 47.56 (Golden Delicious), the chroma* value ranged from 30.45 (Starking Delicious) to 47.89 (Golden Delicious), and the hue* value ranged from 23.19 (Starking Delicious) to 105.79 (Granny Smith). In their study conducted in the Konya Plain, Arıkan et al. (2015) reported L* values of Fuji: 26.15, Golden Delicious: 38.34, and seed counts of Fuji: 8.83 and Golden Delicious: 8.55. Öztürk and Öztürk (2016), in their study under Samsun ecological conditions, determined the skin color L* values of Golden Delicious: 88.04, Granny Smith: 87.54, Starkrimson Delicious: 57.19; a* values of Golden Delicious: 21.25, Granny Smith: 19.06, Starkrimson Delicious: 23.49; and b* values of Golden Delicious: 44.13, Granny Smith: 30.96, Starkrimson Delicious: 19.72. Turan and Karlıdağ (2022), in their study to determine the performance of some apple varieties grown in the plain conditions of Malatya province, found that the fruit skin color values ranged as L* value 81.46 (Golden Delicious) - 53.7 (Starkrimson Delicious), a* value Pink Lady (31.11) - Granny Smith (-15.56), and b* value Granny Smith (46.1) - Starkrimson Delicious (19.2). L* (Brightness): Golden Delicious and Granny Smith varieties stood out with their bright color characteristics, while Starkrimson Delicious ex-

hibited dark and dull color characteristics. This is an important visual feature that influences consumer preferences. In the study, a* and b* Values: The skin color of the varieties varied from red to green and from yellow to blue. While Granny Smith and Golden Delicious exhibited more green and light tones, Starkrimson and Starking Delicious stood out with more red and yellow tones. Additionally, Chroma* and Hue*: These parameters reflect the color intensity and tone characteristics of the fruit skin, emphasizing the importance of apple varieties both for fresh consumption and market aesthetics. These results demonstrate the necessity of considering color parameters in apple cultivation and marketing strategies. Furthermore, the impact of ecological conditions on color values is also significant.

Table 6. Average L*, a*, b* color values results for 2023-2024

Varieties	L*	a*	b*	Chroma*	Hue *
Starking Delicious	38.42±0.46d	27.98±1.32a	11.96±0.56d	30.45±1.08c	23.19±1.75d
Fuji	50.08±2.82c	24.06±0.40b	20.86±0.62c	31.84±0.60c	40.92±0.77c
Granny Smith	61.42±1.43b	-11.03±0.35d	39.10±2.29b	40.63±2.25b	105.79±0.76a
Golden Delicious	75.81±1.07a	-5.52±0.66c	47.56±1.33a	47.89±1.29a	96.64±0.89b
LSD	ns	ns	ns	ns	ns

Mean values in the column followed by the same letter(s) are not significantly different at ($p<0.05$). ns: No significant

The findings related to fruit size obtained in this study are generally consistent with other studies in the literature. Similar differences were observed in the research conducted by Seymen and Polat (2015), and it was stated that this situation is due to year-to-year phenological changes caused by climate. The differences observed among varieties are thought to stem from factors such as rootstock type, genetic characteristics of the variety, cultural practices (irrigation, fertilization, pruning,), climatic conditions, soil structure, and tree age. This situation once again highlights the importance of environmental and agricultural practices on variety performance in apple cultivation. Evaluating the suitability of varieties to the region where they are grown is of critical importance for optimal yield and quality. The correlation between the apple varieties used in the study is presented in Figure 3.

	Year	Fruit Weight	Fruit length	Fruit width	Fruit shape index	Fruit stalk length	Fruit stalk thickness	Fruit stalk cavity width	Fruit stalk cavity depth	Fruit calyx cavity width	Fruit calyx cavity depth	Seed Count	Seed length	Seed width	Seed thickness	Seed weight	Seed cavity length	Seed cavity width	Peel thickness	L*	a*	b*	Croma*	Hue*	Ph	SSC	Titratable acidity
Year	1																										
Fruit Weight	-0.14	1																									
Fruit length	0.29	0.21	1																								
Fruit width	0.24	0.54	0.49	1																							
Fruit shape index	-0.02	-0.42	0.32	-0.67	1																						
Fruit stalk length	0.02	-0.13	0.14	-0.06	0.18	1																					
Fruit stalk thickness	-0.10	0.33	0.33	0.68	-0.46	-0.02	1																				
Fruit stalk cavity width	0.06	0.57	0.50	0.78	-0.41	0.19	0.51	1																			
Fruit stalk cavity depth	0.14	0.45	0.37	0.61	-0.33	0.33	0.39	0.50	1																		
Fruit calyx cavity width	0.05	0.67	-0.11	0.48	-0.64	-0.31	0.30	0.45	0.12	1																	
Fruit calyx cavity depth	0.10	0.47	0.56	0.58	-0.15	-0.04	0.28	0.51	0.39	0.39	1																
Seed Count	-0.20	0.60	-0.27	0.38	-0.64	-0.53	0.15	0.21	0.16	0.72	0.25	1															
Seed length	-0.10	0.19	-0.26	-0.28	0.10	-0.39	-0.58	-0.24	-0.09	0.10	-0.11	0.56	1														
Seed width	-0.02	-0.05	-0.45	-0.45	0.12	-0.39	-0.60	-0.48	-0.39	-0.07	-0.41	0.35	0.86	1													
Seed thickness	-0.04	0.09	-0.47	-0.38	0.02	-0.41	-0.59	-0.41	-0.24	0.03	-0.39	0.47	0.92	0.96	1												
Seed weight	0.10	0.46	0.28	0.81	-0.65	0.12	0.58	0.58	0.59	0.62	0.66	0.41	-0.33	-0.54	-0.48	1											
Seed cavity length	-0.04	-0.06	-0.10	-0.30	0.22	-0.38	-0.25	-0.30	-0.39	-0.12	-0.42	-0.12	0.19	0.41	0.33	-0.48	1										
Seed cavity width	-0.18	0.16	-0.18	0.02	-0.18	-0.70	0.08	-0.23	-0.16	0.10	-0.21	0.43	0.44	0.58	0.53	-0.18	0.69	1									
Peel thickness	-0.20	-0.42	-0.38	-0.74	0.48	-0.17	-0.66	-0.63	-0.72	-0.50	-0.60	-0.20	0.44	0.73	0.60	-0.84	0.52	0.33	1								
L*	-0.03	-0.52	-0.27	-0.81	0.66	-0.01	-0.74	-0.68	-0.51	-0.60	-0.46	-0.26	0.57	0.74	0.63	-0.82	0.28	0.16	0.84	1							
a*	0.00	0.61	0.41	0.80	-0.51	0.19	0.72	0.77	0.70	0.50	0.68	0.29	-0.40	-0.70	-0.57	0.81	-0.58	-0.33	-0.91	-0.85	1						
b*	-0.02	-0.57	-0.30	-0.83	0.65	-0.10	-0.77	-0.72	-0.57	-0.61	-0.56	-0.30	0.53	0.73	0.63	-0.88	0.43	0.24	0.89	0.97	-0.93	1					
Croma*	-0.04	-0.61	-0.20	-0.86	0.78	0.02	-0.74	-0.67	-0.54	-0.70	-0.49	-0.46	0.40	0.58	0.46	-0.90	0.38	0.09	0.83	0.96	-0.87	0.97	1				
Hue*	0.00	-0.57	-0.43	-0.80	0.50	-0.21	-0.75	-0.77	-0.69	-0.47	-0.66	-0.22	0.49	0.76	0.65	-0.81	0.56	0.34	0.92	0.88	-0.99	0.95	0.87	1			
Ph	0.00	0.29	0.57	0.57	-0.13	0.49	0.68	0.55	0.61	0.05	0.60	-0.14	-0.60	-0.80	-0.76	0.62	-0.63	-0.52	-0.76	-0.60	0.84	-0.72	-0.58	-0.86	1		
SSC	-0.04	0.80	0.03	0.64	-0.66	-0.32	0.29	0.60	0.48	0.78	0.47	0.87	0.38	0.06	0.22	0.58	-0.26	0.19	-0.52	-0.51	0.62	-0.57	-0.66	-0.55		1	
Titratable acidity	-0.02	0.17	-0.28	-0.20	-0.02	-0.05	-0.52	-0.19	-0.06	0.23	0.10	0.51	0.81	0.72	0.72	-0.02	-0.07	0.18	0.27	0.48	-0.25	0.37	0.25	0.33	-0.37	0.35	1

Figure 3. Correlation coefficients between the characteristics examined among apple varieties

4. CONCLUSION

The Konya Plain, with its vast agricultural lands, is a significant region in Turkey that stands out for the cultivation of many agricultural products. Apple cultivation is carried out in many regions of our country, and this activity is increasing day by day. However, the preference for old apple varieties with low commercial value in newly established orchards leads to marketing problems. Especially the Ereğli district of Konya, where our study was conducted, is among the regions where apple production areas are rapidly expanding. In this study, the phenological, pomological, and yield characteristics of the Golden Delicious, Starkrimson Delicious, Granny Smith, and Fuji apple varieties were examined during the years 2023-2024. The differences observed in the pomological and chemical characteristics of apple varieties highlight the importance of genetic diversity, growing conditions, and ecological factors. According to the results of the study, the Fuji and Golden Delicious varieties exhibited superior characteristics in terms of physical and chemical quality parameters. These data can guide producers in making the right variety selection for regional apple cultivation. Cultivating varieties that align with consumer preferences can enhance marketing success in regional apple production. In the future, studies on storage conditions and post-harvest durability will contribute to further improving these results. The findings obtained are guiding in nature for achieving more efficient and high-quality apple production in Ereğli and similar regions. Future research should focus on long-term phenological monitoring and climate adaptation strategies to ensure sustainable apple cultivation in the region.

Conflict of Interest

The authors declare that there is no conflict of interest.

Ethics

This study does not require ethics committee approval.

Author Contribution Rates

Design of Study: B.İ (20), Y.P (40), H.E (20), N.E.K(20)

Data Acquisition: Y.P (30), H.E (25), B.İ (25), N.E.K(20)

Data Analysis: Y.P (30), H.E (20), B.İ (30), N.E.K(20)

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