



# Phenological, morphological and yield characteristics of apple cultivars grown on different clonal rootstocks in Ordu ecology

## *Ordu ekolojisinde farklı klonal anaçlar üzerinde yetiştirilen elma çeşitlerinin fenolojik, morfolojik ve verim özellikleri*

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### ABSTRACT

This study was carried out to determine the phenological, morphological traits and yield values of some standard apple cultivars grafted on M9 and MM106 clonal rootstocks in Ordu (Türkiye) ecological conditions. In this context, in regional conditions, blooming periods, harvest dates, rootstock and trunk development, yield and yield efficiency values of rootstock/cultivar combinations were examined. According to the research findings, the earliest first bloom (14/11 April) and full bloom (18/17 April) were observed in the Granny Smith/M9 combination, while the earliest harvest was realized in Mondial Gala/M9 (11 September, 29 August) and Galaxy Gala/MM106 (29 August) combinations. Also, the yield was determined between 2.49 kg tree<sup>-1</sup> (Fuji/MM106)-8.95 kg tree<sup>-1</sup> (Mondial Gala/M9), and yield efficiency was determined between 0.14 kg cm<sup>-2</sup> (Fuji/MM106)-1.16 kg cm<sup>-2</sup> (Mondial Gala/M9). In the principal component analysis results, the first component was associated with crown width, canopy volume, shoot diameter, yield, yield efficiency, and shoot length and explained 48.3% of the total variation. The second component explained 33.1% of the total variation of the obtained data and was determined to be related to crown height, rootstock diameter, and trunk diameter. As a result, it was concluded that the morphological development and phenological stages of the examined rootstock/cultivar combinations were generally suitable for the ecological conditions of Ordu province.

**Key Words:** Blooming, Canopy volume, *Malus domestica*, Rootstock, Yield efficiency

### ÖZ

Bu çalışma, Ordu (Türkiye) ekolojik koşullarında M9 ve MM106 klon anaçlarına aşılı bazı standart elma çeşitlerinin fenolojik, morfolojik özellikleri ve verim değerlerinin belirlenmesi amacıyla yapılmıştır. Bu kapsamda, bölge koşulları altında anaç/çesit kombinasyonlarının çiçeklenme dönemleri, hasat tarihleri, anaç ve gövde gelişimi, verim ve verim etkinlik değerleri incelenmiştir. Araştırma bulgularına göre en erken ilk çiçeklenme (14/11 Nisan) ve tam çiçeklenme (18/17 Nisan) Granny Smith/M9 kombinasyonunda gözlemlenirken, en erken hasat Mondial Gala/M9 (11 Eylül, 29 Ağustos) ve Galaxy Gala/MM106 (29 Ağustos) kombinasyonlarında gerçekleşmiştir. Ayrıca, verim 2.49 kg ağaç<sup>-1</sup> (Fuji/MM106)-8.95 kg ağaç<sup>-1</sup> (Mondial Gala/M9) arasında, verim etkinliği ise 0.14 kg cm<sup>-2</sup> (Fuji/MM106)-1.16 kg cm<sup>-2</sup> (Mondial Gala/M9) arasında tespit edilmiştir. Temel bileşen analizi sonuçlarında, birinci bileşen taç genişliği, kanopi hacmi, sürgün çapı, verim, verim etkinliği ve sürgün uzunluğu ile ilişkilendirilmiş ve toplam varyasyonun %48.3'ünü açıklamıştır. Elde edilen verilerdeki toplam değişimin

%33.1'ini aıklayan ikinci bileşenin ise ta y kseklilii, ana apı ve g vde apı ile iliřkili olduėu belirlenmiřtir. Sonu olarak, incelenen ana/eřit kombinasyonlarının morfolojik geliřim ve fenolojik evrelerinin Ordu ili ekolojik kořullarına genel olarak uygun olduėu kanaatine varılmıřtır.

**Anahtar Kelimeler:** ieklenme, Kanopi hacmi, *Malus domestica*, Ana, Verim etkinliėi

## Introduction

Apple (*Malus domestica* Borkh.) is one of today's most cultivated temperate climate-type fruits. Its high adaptability has facilitated the spread and cultivation of this species over large areas. The fact that T rkiye is among the homeland of apples has led to the emergence of many local types and has revealed a tremendous genetic richness (Osmanoėlu and Balta, 2021). However, considering the developments in modern agricultural techniques and consumer preferences, ensuring the standard in production and growing quality and high-yielding products have increased their importance day by day. As it is known, high yield is one of the most important goals of fruit breeding (Byrne, 2012). In addition, there are important breeding targets for developing product quantity and morphological characteristics such as low cold damage and resistance to diseases and pests.

Especially with the development of dwarf clonal rootstocks, intensive planting systems and pruning applications have increased the yield from the unit area in apple production. Rootstocks affect yield, growth, scion development, fruit quality and resistance to biotic-abiotic stress conditions (Wang et al., 2019). Like most fruit species, the apple is susceptible to spring (late) frosts. It has been reported that a single frost event during the flowering period can damage or kill flower buds (Eccel et al., 2009). It has also been reported that adverse weather conditions reduce fruit quality and product quantity (Dalhaus et al., 2020).

Therefore, through adaptation studies, determining the yield performances, morphological developments, and phenological characteristics of popular cultivars demanded by the consumer in the ecological conditions of different regions of T rkiye will help the selection

of cultivars in new orchards to be established. In this way, the factors that can reduce production and quality will be minimized by choosing high-yielding cultivars that are resistant to cold.

The main aim of this study was out to evaluate the morphological, phenological and yield characteristics of rootstocks/standard apple cultivar combinations grafted on M9 full-dwarf and MM106 semi-dwarf clonal rootstocks grown in Ordu (T rkiye) ecology condition.

## Materials and Methods

### Plant materials

This study was performed in Ordu University Faculty of Agriculture Application and Research Field with Mondial Gala, Jeromine and Granny Smith cultivars grafted on M9 clonal rootstock, and Granny Smith, Fuji, Galaxy Gala, Red Chief and Scarlett Spur cultivars grafted on MM106 clonal rootstock in 2017-2018. The altitude of the study area is 10 m. Planting of the cultivar/rootstock combinations examined was carried out in 2015. The plot with the cultivars grafted on M9 rootstock was 3.0 x 1.2 m, and the plot with cultivars grafted on MM106 rootstock was established in 3.5 x 3.0 m row spacing. All cultural practices, such as pruning, irrigation, fertilization, and weed control, were carried out regularly in the study area.

According to the climate data for many years in Ordu (1959-2022), the average highest temperature is 18.4  C, the lowest temperature is 11.3  C, the annual average temperature is 14.5  C, and the annual average precipitation is 1049.1 mm (Anonymous, 2023).

### 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 strength were selected. Observations and measurements were carried out on trees in 2017 (3 years-old) and 2018 (4 years-old). However, since blooming and fruit set did not occur in Fuji, Galaxy Gala, Red Chief, and Scarlett Spur cultivars grafted on MM106 rootstock in 2017, these characteristics could not be examined.

Phenologically, budburst, first bloom, full bloom, end of bloom, number of days from full bloom to harvest, and harvest dates were observed in the study (Yaşasın et al., 2006; Yarılgaç et al., 2009; Ozturk and Ozturk, 2016). Morphologically, crown height (cm), crown width (cm), canopy volume (m<sup>3</sup>), rootstock diameter (mm), trunk diameter (mm), and shoot diameter (mm) were determined (Baytekin and Akça, 2011; Balta et al., 2015).

The yield of the cultivars was determined by weighing the product obtained from each tree (kg tree<sup>-1</sup>), while the yield efficiency (kg cm<sup>-2</sup>) was calculated by dividing the total yield of the tree by the trunk cross-sectional area (Ozkan et al., 2009).

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. The biplot graph was constituted using yield and morphologic traits determined in the rootstock/cultivar combinations investigated.

## Results and Discussion

Budburst, first bloom, full bloom, end of bloom, harvest date, and full bloom to harvest date of the cultivars were determined by making phenological observations in 2017 and 2018 (Table 1, Table 2). However, due to the absence of blooming in Fuji, Galaxy Gala, Red Chief, and Scarlet Spur cultivars grafted on MM106 rootstock in the observations made in 2017, data on these observations could not be obtained. In this context, the first bloom occurred on April 14 (Granny Smith/M9) at the earliest and April 19 (Mondial Gala/M9, Jeromine/M9) at the latest in 2017. Full bloom was observed between April 18 (Granny Smith/M9) and April 25 (Mondial

Gala/M9, Jeromine/M9). The days from full bloom to harvest ranged from 141 days (Mondial Gala/M9) to 184 days (Granny Smith/M9). In 2018, however, the first bloom of the cultivars occurred on April 11 (Granny Smith/M9, Scarlet Spur/MM106) at the earliest and April 18 (Mondial Gala/M9) at the latest. Full blooming was observed between April 16 (Scarlet Spur/MM106) and April 24 (Mondial Gala/M9). The days from full bloom to harvest ranged from 129 days (Mondial Gala/M9) to 178 days (Granny Smith/M9).

The earlier blooming period in apple cultivation might risk damage to spring frosts in some regions (Legave et al., 2013). For this reason, it is considered an important criterion to know the bloom dates during the establishment phase of the orchards. In addition, it is reported that the date of full bloom is important in determining the harvest time in cultivars (Akçay et al., 2009; Arıkan et al., 2015). Determination of phenological stages also contributes to implementing some cultural practices such as fruit thinning, pollination, and disease-pest control, along with comparing the adaptability of different cultivars to a region and observing the effects of environmental factors (Petri et al., 2012). Generally, there were differences in blooming dates between years in the present study. This may be due to climatic events that change over the years (Karşı and Aslantaş, 2016; Ozturk and Ozturk, 2016). In a study carried out in Konya ecological conditions, it was reported that the first bloom of Fuji, Braeburn, Jonagold, Golden Delicious, Summer Red, Jersey Mac and Red Chief cultivars grafted on M9 and M26 rootstock occurred between April 11 (Summer Red) - May 13 (Braeburn) and full bloom occurred between May 3 (Summer Red) - May 19 (Braeburn) (Arıkan et al., 2015). In a study conducted with Cooper 7 SB2, Golden Delicious, Granny Smith, Jersey Mac, Red Chief, Starkrimson Delicious, and Super Chief cultivars grafted on MM106 rootstock in Samsun ecology in 2013 and 2014, the first bloom was found on 8 April (Jersey Mac, Red Chief)-24 April (Cooper 7 SB2) and 27

March (Jersey Mac)-13 April (Cooper 7 SB2, Golden Delicious), full bloom 22 April (Jersey Mac, Red Chief)-30 April (Cooper 7 SB2), and 10 April (Jersey Mac)-20 April (Golden Delicious, Super Chief), harvest 7 July (Jersey Mac)-16 October (Granny Smith) and 8 July (Jersey Mac)-16 October (Granny Smith), the number of days from full bloom to harvest was reported between 76 (Jersey Mac)-141 (Red Chief) and 89 (Jersey Mac)-187 (Granny Smith) (Ozturk and Ozturk, 2016).

Accordingly, it is seen that there are differences between phenological dates in studies conducted in different parts of Türkiye. There are also phenological differences in our study. It is thought that cultivar and altitude (Bayazıt et al., 2019) precipitation, photoperiod, and solar radiation (Cho et al., 2021), temperature (Delgado et al., 2021), and cultural practices (İkinci and Bolat, 2016) may affect these differences.

Table 1. Bud burst, first bloom and full bloom of apple cultivars grafted on M9 and MM106 clonal rootstocks

Cultivar/Rootstock	Bud Burst		First Bloom		Full Bloom	
	2017	2018	2017	2018	2017	2018
Mondial Gala/M9	27.03	23.03	19.04	18.04	25.04	24.04
Jeromine/M9	28.03	25.03	19.04	16.04	25.04	22.04
Granny Smith/M9	29.03	29.03	14.04	11.04	18.04	17.04
Granny Smith/MM106	29.03	28.03	15.04	14.04	20.04	18.04
Fuji/MM106	nd*	29.03	nd	15.04	nd	19.04
Galaxy Gala/MM106	nd	28.03	nd	15.04	nd	21.04
Red Chief/MM106	nd	30.03	nd	14.04	nd	18.04
Scarlet Spur/MM106	nd	30.03	nd	11.04	nd	16.04

\*nd, non-defined.

Table 2. End of bloom, harvest date and full bloom to harvest date of apple cultivars grafted on M9 and MM106 clonal rootstocks

Cultivar/Rootstock	End of Bloom		Harvest Date		FBTHD*	
	2017	2018	2017	2018	2017	2018
Mondial Gala/M9	30.04	29.04	11.09	29.08	141	129
Jeromine/M9	30.04	28.04	4.10	20.09	164	153
Granny Smith/M9	25.04	24.04	17.10	10.10	184	178
Granny Smith/MM106	28.04	25.04	17.10	10.10	182	177
Fuji/MM106	nd*	24.04	nd	10.10	nd	176
Galaxy Gala/MM106	nd	27.04	nd	29.08	nd	132
Red Chief/MM106	nd	27.04	nd	20.09	nd	157
Scarlet Spur/MM106	nd	24.04	nd	20.09	nd	159

\*FBTHD, Full bloom to harvest date. \*\*nd, non-defined.

Morphologically determined crown height, crown width and canopy volume values in the examined cultivars were presented in Table 3, rootstock diameter, trunk diameter and shoot diameter values were shown in Table 4 and shoot length values were presented in Table 5. Accordingly, in the measurements made in 2017, the crown height of the cultivars was 150.83 cm (Jeromine/M9)-191.75 cm (Fuji/MM106); crown width 69.00 cm (Granny Smith/MM106)-142.00 cm (Jeromine/M9); canopy volume 0.32 m<sup>3</sup> (Granny Smith/MM106)-1.19 m<sup>3</sup> (Jeromine/M9); rootstock diameter 3.53 cm (Granny Smith/M9)-4.68 cm (Galaxy Gala/MM106); trunk diameter

2.45 cm (Granny Smith/MM106)-3.47 cm (Fuji/MM106); shoot diameter 4.36 mm (Jeromine/M9)-6.32 mm (Scarlet Spur/MM106) and shoot length 37.30 cm (Mondial Gala/M9)-74.20 cm (Red Chief/MM106). In 2018, the crown height of the cultivars was 160.00 cm (Red Chief/MM106)-217.5 cm (Galaxy Gala/MM106); crown width 106.67 cm (Scarlet Spur/MM106)-185.83 cm (Galaxy Gala/MM106); canopy volume 0.83 m<sup>3</sup> (Granny Smith/MM106)-2.95 m<sup>3</sup> (Galaxy Gala/MM106); rootstock diameter 4.85 cm (Jeromine/M9)-6.53 cm (Scarlet Spur/MM106); trunk diameter 3.11 cm (Jeromine/M9)-4.89 cm (Scarlet Spur/MM106); shoot diameter was

determined as 5.35 mm (Jeromine/M9)-7.55 mm (Scarlet Spur/MM106) and shoot length 43.80 cm (Scarlet Spur/MM106)-59.90 cm (Granny Smith/M9). In the morphological measurements made in this study, the highest values of crown height, crown width, and canopy volume were obtained from the Galaxy Gala/MM106 combination. Among other cultivars, it can be said that these traits have higher values in cultivars grafted on M9 rootstock than in cultivars grafted on MM106. There was no significant difference

between the cultivars' rootstock diameter and trunk diameter values ( $p < 0.05$ ). However, the highest rootstock and trunk diameter values were determined in Galaxy Gala/MM106 cultivar. Therefore, it can be said that Galaxy Gala/MM106 cultivar stands out in tree development in Ordu ecology. In addition, it was determined that the highest shoot diameter development was in Scarlet Spur/MM106 (6.3 mm) and Red Chief/MM106 (6.0 mm), and the shoot length was in Red Chief/MM106 (63.8 mm).

Table 3. Crown height, crown width and canopy volume data of apple cultivars grafted on M9 and MM106 clonal rootstocks

Cultivar/Rootstock	Crown Height (cm)			Crown width (cm)			Canopy volume (m <sup>3</sup> )		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	169.2	200.0	184.6 a	123.8	173.3	148.5 a	1.02	2.36	1.7 ab
Jeromine/M9	150.8	180.8	165.8 a	142.0	136.7	139.3 ab	1.20	1.33	1.3ab
Granny Smith/M9	172.0	197.5	184.8 a	107.5	142.5	125.0 abc	0.79	1.60	1.2 ab
Granny Smith/ MM106	171.3	167.5	169.4 a	69.0	112.5	90.8 c	0.32	0.84	0.6 b
Fuji/MM106	191.8	180.0	185.9 a	102.5	134.2	118.3 abc	0.79	1.32	1.1 ab
Galaxy Gala/MM106	165.1	217.5	191.3 a	120.0	185.8	152.9 a	0.93	3.00	2.0 a
Red Chief/MM106	173.1	152.5	162.8 a	97.5	123.3	110.4 abc	0.65	0.92	0.8 b
Scarlet Spur/MM106	159.6	201.7	180.6 a	95.5	113.3	104.4 bc	0.57	1.02	0.8 b

The differences among the means indicated with different lower-case letters vertically are significant (Tukey's test,  $P < 0.05$ ).

Table 4. Rootstock diameter, trunk diameter and shoot diameter of apple cultivars grafted on M9 and MM106 clonal rootstocks

Cultivar/Rootstock	Rootstock diameter (mm)			Trunk diameter (mm)			Shoot diameter (mm)		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	39.6	60.2	49.9 a	25.4	35.8	30.6 a	4.7	6.2	5.5 ab
Jeromine/M9	41.9	48.5	45.2 a	24.8	31.1	27.9 a	4.4	5.4	4.9 b
Granny Smith/M9	35.3	55.6	45.4 a	24.5	39.7	32.1 a	5.0	6.2	5.6 ab
Granny Smith/MM106	37.9	56.7	47.3 a	28.4	42.8	35.6 a	5.5	5.6	5.5 ab
Fuji/MM106	46.1	64.7	55.4 a	34.7	47.1	40.9 a	5.7	5.5	5.6 ab
Galaxy Gala/MM106	46.8	79.0	62.9 a	33.5	51.6	42.6 a	5.3	5.8	5.5 ab
Red Chief/MM106	40.2	60.8	50.5 a	32.0	43.9	38.0 a	5.8	6.1	6.0 a
Scarlet Spur/MM106	41.5	62.6	52.1 a	30.2	45.9	38.1 a	5.7	6.8	6.3 a

The differences among the means indicated with different lower-case letters vertically are significant (Tukey's test,  $P < 0.05$ ).

Also, the yield and yield efficiency data determined in the study were shown in Table 5. The yield per tree obtained from the cultivars was 1.27 kg tree<sup>-1</sup> (Granny Smith/MM106)-5.57 kg tree<sup>-1</sup> (Mondial Gala/M9). Yield efficiency was determined between 0.20 kg cm<sup>-2</sup> (Granny Smith/MM106)-1.10 kg cm<sup>-2</sup> (Mondial Gala/M9) in 2017. In 2018, the yield per tree obtained from the cultivars was determined as 2.49 kg tree<sup>-1</sup> (Fuji/MM106)-12.49 kg tree<sup>-1</sup> (Granny Smith/M9), while the yield efficiency was 0.14 kg cm<sup>-2</sup> (Fuji/MM106)-1.22 kg cm<sup>-2</sup> (Mondial Gala/M9).

The yield characteristics were higher in M9

rootstock grafted cultivars in the study. On the basis of cultivars, it was observed that Mondial Gala/M9 and Granny Smith/M9 had the highest values. Previously, Soylu et al. (2003) reported that the highest yield and yield efficiency among the cultivars grafted on MM106 rootstock was obtained from the Granny Smith cultivar in Görükle (Bursa) conditions. Ceylan (2008) expressed that Granny Smith had the highest yield in cultivars grafted on M9 and MM106 rootstocks in Niğde conditions, and Mondial Gala and Galaxy Gala cultivars had the lowest. Dousti (2010) stated that the highest yield characteristics

were obtained from Fuji cultivar in the study conducted with cultivars grafted on M9 rootstock in Ankara conditions. Accordingly, it has been observed that there are some similarities and differences between the findings obtained from

the study and the studies in the literature. As a matter of fact, the location of the orchard, regional differences, rootstock/cultivar combinations, tree age, and cultural practices can affect yield characteristics (Balta et al., 2020).

Table 5. Shoot length, yield and yield efficiency of apple cultivars grafted on M9 and MM106 clonal rootstocks

Cultivar/Rootstock	Shoot length (mm)			Yield (kg tree <sup>-1</sup> )			Yield efficiency		
	2017	2018	Mean	2017	2018	Mean	2017	2018	Mean
Mondial Gala/M9	37.3	57.4	47.4 b	5.57	12.34	8.95 a	1.10	1.22	1.16 a
Jeromine/M9	43.0	51.0	47.0 b	3.25	8.46	5.85 a	0.68	1.14	0.91 a
Granny Smith/M9	50.5	59.9	55.2 ab	3.88	12.49	8.19 a	0.82	1.02	0.92 a
Granny Smith/MM106	62.6	41.3	51.9 ab	1.27	6.42	3.85 a	0.21	0.46	0.33 b
Fuji/MM106	57.0	49.5	53.3 ab	nd	2.49	2.49 a	nd	0.14	0.14 b
Galaxy Gala/MM106	49.6	46.3	48.0 ab	nd	3.69	3.69 a	nd	0.25	0.25 b
Red Chief/MM106	67.7	59.9	63.8 a	nd	3.69	3.69 a	nd	0.25	0.25 b

The differences among the means indicated with different lower-case letters vertically are significant (Tukey's test, P < 0.05).

As a result of principal component analysis, two components with an eigenvalue above one was formed. The first two components formed explained 81.5% of the data. PC 1 was associated with crown width, canopy, shoot diameter, yield,

yield efficiency, and shoot length accounting for 48.3% of the data. PC 2, explaining 33.1% of the data, was related to crown height, rootstock diameter, and trunk diameter (Figure 1).

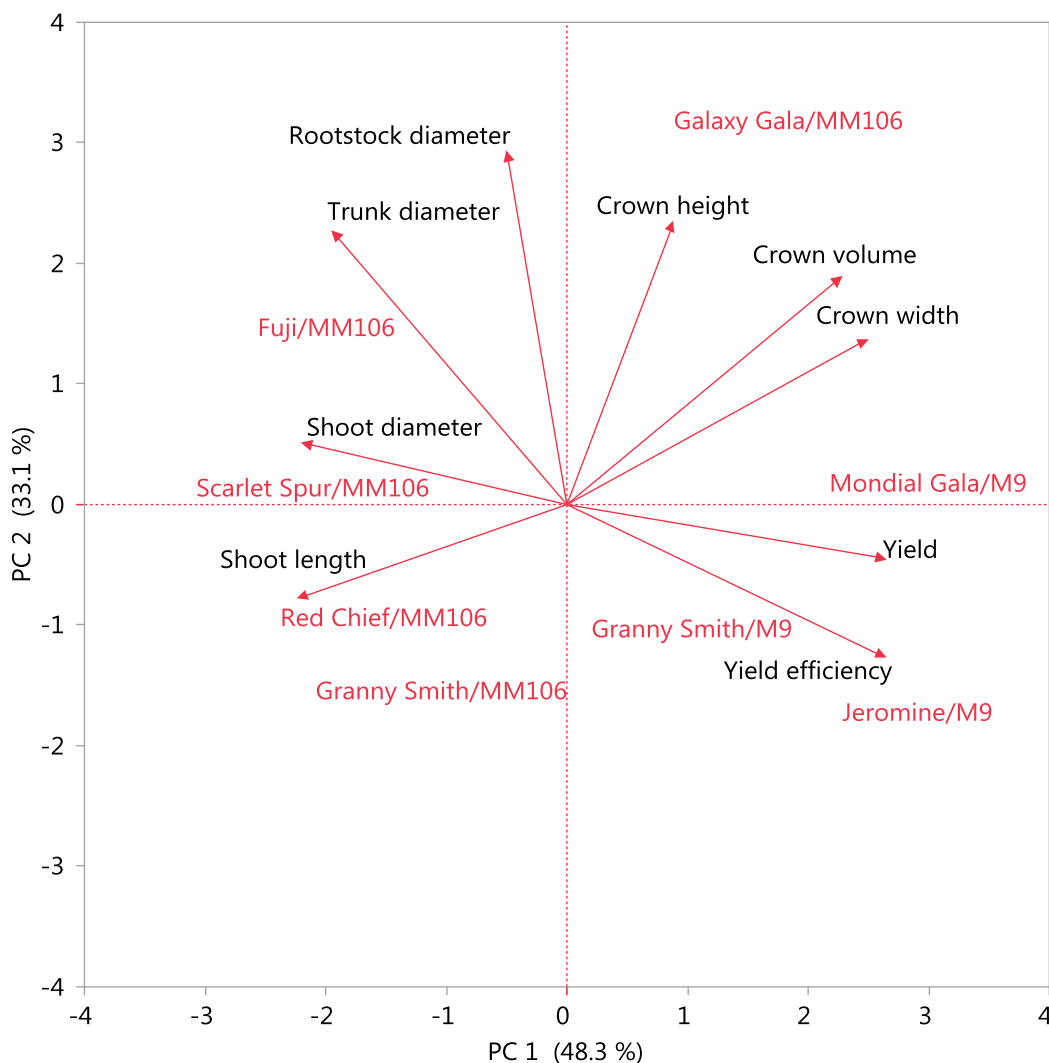


Figure 1. Component plot of the two-principal component in the investigated apple cultivars based on morphological characteristics

## Conclusion

In the study, phenological observations, morphological developments and yield characteristics were determined Granny Smith, Mondial Gala, and Jeromine apple cultivars grafted on M9 clonal rootstock, and Granny Smith, Fuji, Galaxy Gala, Red Chief, and Scarlet Spur apple cultivars grafted on MM106 clonal rootstock. The findings showed that rootstock/cultivar combinations are suitable for cultivation under the ecological conditions of the region. Among the examined cultivars, Mondial Gala/M9, Granny Smith/M9, and Jeromine/M9 combinations had the highest results in terms of yield and yield efficiency. Therefore, it was observed that the cultivars grafted on M9 rootstock came to the forefront in this respect compared to MM106 rootstock. It is thought that maintaining phenological and morphological measurements on these cultivars is important in revealing the yield characteristics more clearly. In conclusion, the findings obtained during the study will provide important information to the region producer about the use of dwarf and semi-dwarf rootstocks, one of the important steps of modern fruit cultivation, and the performance of cultivars grafted on these rootstocks.

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**Author contributions:** TY: Methodology, investigation, conceptualization. SU Methodology, investigation, conceptualization, validation, writing - original draft, visualization, formal analysis. OK: Methodology, investigation, conceptualization, validation, review and editing, formal analysis. UA: Formal analysis, data curation. BÖ: Methodology, investigation,

conceptualization, validation, review and editing, visualization.

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