

## PERFORMANCE OF SOME APPLE CULTIVARS AND ROOTSTOCKS IN SUBTROPICAL ECOLOGICAL CONDITIONS OF MEDITERRANEAN REGION IN TURKEY

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### ABSTRACT

The subtropical ecology of the Mediterranean region in Turkey has an important potential based on precocity for both stone and soft fruits. The aim of this study is to determine the yield and fruit quality properties of some apple cultivars on dwarf (M9) and semi-dwarf (MM106) rootstocks under the subtropical ecological conditions. Harvesting date, yield and pomological characteristics of apple cultivars ‘Vista Bella’, ‘Jerseymac’, ‘Starking Delicious’, ‘Golden Delicious’, and ‘Granny Smith’ were determined. The highest yield per tree was recorded from trees on rootstocks MM106, whereas the highest yield per hectare was detected from M9 rootstocks. Fruit quality varied dependent on cultivars but rootstocks were effective only on TSS and fruit skin color such as  $L^*$ ,  $b^*$ ,  $C$ , and  $h^\circ$ . There was not found any effect of rootstocks on the other fruit characteristics such as fruit weight, pH, fruit length, and firmness. Result of this study revealed that summer apple cultivars were found to be very promising on both rootstocks (M9 and MM106) in the subtropical ecological conditions of the Mediterranean region in Turkey.

**Key words:** apple cultivars, rootstock, yield, fruit quality, subtropical ecology

### INTRODUCTION

The cultivated apple, *Malus domestica* Borkh, belongs to the *Rosaaceae* (Rose) family, and the subfamily of *Pomoideae*; along with pear, quince, loquat and medlar [Özbek 1978]. Although Anatolia, Caucasia, Turkistan, and Europe are origin for the domestic apple (*Malus domestica* Borkh.), it is also grown in continental climates in the Northern and Southern Hemispheres now. Apple has been cultivated since ancient times and it is one of the most important fruit for human consumption. For some reasons, such as its great variety in colors, flavors, flesh textures, and other features [Mukhtar et al. 2010, Bozbuğa and Pırlak 2012] the apple tree is one

of the most widely cultivated plants in the world with more than 7,500 known cultivars and rootstocks.

Turkey is one of the major apple producing countries, with approximately 3,128,000 tones apple production in 2013 [FAO 2013]. Most of the known apple cultivars grown in Turkey are winter varieties such as Golden Delicious, Starking Delicious, Granny Smith and Amasya. In newly planted apple orchards, new cultivars are harvested between June and October. By increasing production of mid-season apple cultivars, Mondial Gala and Galaxy Gala may supply more profit and also prevent the accumulation of crops in the late season. However, in recent years,

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early varieties (such as Vista Bella, Jersey mac, Stark Earliest, Anna etc.) are grown in Hatay, Adana, Mersin and Antalya provinces that have subtropical conditions in Turkey.

Dwarfing rootstocks have become widely acceptable in the industry as a tool to increase orchard efficiency because they influence the size of tree, yield and planting density per unit area [Barritt et al. 1995]. Modern orchards planting systems are based on higher tree densities ranging from 1,000 to 6,000 trees per hectare and some up to 10,000 trees per hectare [Robinson 2003]. However, increasing planting density alone does not increase the yield, as planting density and yield are not linearly related and a threshold can be found beyond which a further increase in density may not result in greater yield [Webster 2001, Hampson et al. 2002]. Clonal dwarfing apple rootstocks control scion growth by the reduction of canopy spread, branches compression and tree height. M9 has been introduced as a dwarf that induces excellent yield, precocity, efficiency and large fruit size. Although semi-dwarfing MM106 causes high yield efficiency, fruit size can be smaller than M9 [Ferree and Warrington 2003]. As the effect of rootstocks on quality parameters have not been fully documented so far, we have tried to fill the gap. As defined by Alhinai and Roper [2004], that the effects of rootstock on fruit quality vary under different climatic conditions and they are not stable. There is, however, no universal rootstock for all kinds of soil, climatic conditions, or the various apple cultivars [Czynczyk et al. 2009]. In temperature regions of Turkey, the effect of clonal rootstocks on growth and fruit characteristics of Golden Delicious, Starking Delicious and Granny Smith apple cultivars has been compared in some researches [Ercişli et al. 2000, Tekintaş et al. 2006, Baytekin and Akça 2011, Küçükkeker et al. 2011, Bozbuğa and Pırlak 2012]. However, some trials aim to compare their effect on yield and fruit properties of summer and winter apple cultivars are still lacking more information in subtropical conditions of Mediterranean region of Turkey. The region is very critical due to suitable climate conditions for earliness fruit culture such as apricot, peach, plum, sweet cherry, apple and pear. Hence, it is important to record on yield and fruit properties of

the apple cultivars in the region of ecological conditions. For this reason, the aim of our three-year-study was to determine the effect of two different rootstocks (M9 and MM106) yield and pomological characteristics of five apple cultivars in the subtropical ecological conditions of Mediterranean region in Turkey.

## MATERIALS AND METHODS

### Plant material

The experiment was conducted at Yayladağı, Hatay (latitude 35°58'04"N, longitude 36°00'55"E; altitude 766 m) in the orchard of private sector and this was conducted during three successive seasons in 2013, 2014 and 2015. Regular agricultural practices were applied in orchards. Hatay province has typical Mediterranean climate that yearly average temperatures are ranged from 8.2 to 27.7°C. The maximum summer temperatures reach between June and September, and fruit ripening period are varied between 29.2 and 31.9°C. Majority of precipitation occurs during the winter and spring seasons with 1144 mm per year [TSMS 2015] (tab. 1).

The experiment was conducted on six year old apple cultivars consisting of 'Golden Delicious', 'Starking Delicious', 'Granny Smith', 'Jersey mac' and 'Vista Bella' grafted on dwarf (M9) and semi-dwarf (MM106) rootstocks. Trees were planted in 2007 with four replications at a distance  $3 \times 1.25$  and  $3 \times 2.50$  m for M9 and MM106 rootstocks, respectively.

### Yield and fruit quality analysis

All of the fruit samples were taken during the maturity stage which was visually determined and harvesting date of the cultivars also was determined. On the experimental trees, the number of fruits was counted, yielded (harvested and weighted per tree in kilograms) and weighted. Trunk diameter was measured at a height of 20 cm and was converted to Trunk Cross Sectional Area (TCSA/cm<sup>2</sup>). Average and cumulative yield per tree and yield efficiency of each scion-stock combination were calculated according to harvesting data. The plant yield efficiency (kg cm<sup>-2</sup>) was stated as the ratio of total cumulative yield in kg per final TCSA.

**Table 1.** Meteorological data of Hatay province in the subtropical climate of the eastern Mediterranean region of Turkey (mean of 1975–2015 years)

Month	Temperature (°C)			Total rainfall (mm)
	minimum	maximum	average	
January	4.5	12.3	8.2	182.8
February	5.5	14.5	9.8	164.1
March	8.5	14.8	13.2	141.9
April	12.2	22.7	17.2	102.7
May	16.3	26.5	21.2	92.9
June	20.8	29.2	24.8	20.4
July	23.8	31.2	27.2	24.8
August	24.5	31.9	27.7	5.9
September	21.1	31.1	25.5	42.1
October	15.4	27.6	20.8	77.5
November	9.3	20.1	14.0	115.2
December	5.9	13.9	9.6	173.7

A total of thirty fruits were taken randomly from four directions of trees (north-south-east-west). The used pomological methods were taken from Pırlak et al. [2003]. Fruit weight (g) was measured with a scale which is sensitive to 0.01 g (Precisa XB 2200 C). Fruit length (mm) and diameter (mm), were measured by a digital calibrator (Mitutoyo, 0–150 mm).

Total soluble solids (TSS) content was determined with a hand-held refractometer (NOW, 0–32% Brix) and pH measurements were performed using a pH meter (WTW InoLab pH meter). Acidity (expressed as malic acid %) was determined by titrating with 0.1 N NaOH up to pH 8.10. Seed numbers per four fruit were counted. The flesh firmness was measured using hand penetrometer with 11 mm probe. The firmness was performed in two opposite areas of the equatorial part of the each fruit.

The skin color of the fruits was measured by using a Minolta chroma meter (Chroma Meter CR-300, Minolta Co., Osaka, Japan). Thirty fruits of each cultivar were randomly selected and were measured on the two opposite skin surfaces of fruits. Color characters were expressed as  $L^*$ ,  $a^*$ ,  $C$ , and  $h^\circ$ . The  $L^*$  values indicate darkness and high  $L^*$  values represent lightness. Negative  $a^*$  values indicate green color and positive  $a^*$  values indicate red color. The  $C$  value shows color intensity. The  $h^\circ$ , is a pa-

rameter that has been indicated to be effective in predicting visual color appearance [Francis 1980].

#### Data analysis

The data were analyzed by using SAS software and procedures [SAS 2005]. Analysis of variance (ANOVA) tables were constructed with Fisher's Least Significant Difference (LSD) method at  $p < 0.05$ .

#### RESULT AND DISCUSSION

In general, the fruits were ripened towards the end of June for Jersey mac cultivars and the first week of July for Vista Bella cultivar (tab. 2). Harvest date of the fruits which was the first of the September for Golden Delicious and Starking Delicious cultivars, was approximately the same during the entire experimental period whereas the maturity date for Granny Smith was in the second half of the September (tab. 2). Ozturk et al. [2011] indicated that Jersey mac and Vista Bella cultivars on MM106 are matured in the end of July under East Anatolia conditions. In addition, Ozturk and Ozturk [2016] indicated that Jersey mac on MM106 is ripened on 8 July under Black Sea Region ecological conditions. Ozogun and Dolunay (2011) showed that Jersey mac and Vista Bella are harvested in middle of the July in the Egirdir,

**Table 2.** Harvest date of apple cultivars on M9 and MM106 rootstocks (means of 2013–2015)

Rootstocks	Cultivars				
	Jerseymac	Vista Bella	Golden Delicious	Starking Delicious	Granny Smith
M9	18 June	6 July	9 September	13 September	27 September
MM106	17 June	30 June	9 September	13 September	27 September

Isparta ecology which is between middle Anatolia and Mediterranean region of Turkey. In addition, Imrak et al [2009] indicated that summer apple cultivars grown in subtropical ecology of Turkey 10–15 days are earlier than European apple growing countries. Our results showed that summer apple cultivars are harvested about 10–15 days ago in subtropical conditions of Mediterranean region of Turkey (tab. 2).

As shown in Table 3, Starking Delicious and Jerseymac cultivars revealed a good vigor and growth performance with larger trunk diameter (52.23 and 51.12 mm, respectively) and high trunk cross-sectional area (21.57 and 21.41, respectively). However, as expected, the average trunk diameter and the trunk cross-sectional area on MM106 rootstock (49.87 mm and 20.15 mm, respectively) were larger than the ones that were obtained from M9 rootstock (45.63 mm and 16.98 mm, respectively). Number of fruits per tree or yield per three of Golden Delicious and Granny Smith cultivars were higher than the other cultivars. MM106 rootstock had the higher values for both fruit number and kg per tree (56.11 and 7.89 kg tree<sup>-1</sup> respectively) whereas, there was more yield in cultivars on M9 in hectare (16.17 t ha<sup>-1</sup>) than MM106 (tab. 3). In addition, the yield efficiency was not significantly affected based on rootstocks. Racsco et al. (2004) indicated that the maximum yield values are obtained from M9 compared to MM106. The number of fruits per tree was calculated as 15.3 and 63.9 in 2002 and 2003, respectively, for Granny Smith cultivar on M9 and those fruit numbers for Vista Bella were 6.1 and 48.2 per tree. For the MM106 rootstock the reported fruit numbers are 10.4 and 46.4 per tree for Granny Smith and reported

fruit numbers 10.4 and 51.9 per tree for Vista Bella. Fruits numbers under subtropical climate conditions, in our study, were higher than those reported by Racsco et al. [2004]. Inducing precocity, increasing the efficiency of tree yields assimilated from shoot growth for fruit production, increasing photosynthesis and yield efficiency shoot growth, increasing the exposure to the light in canopy, augmenting competition between vegetative and productive growth [Webster 2001, McAfee and Rom 2003] and enhancing setting are some of the advantages to use the dwarfing rootstock [Costes and García-Villanueva 2007, Seleznyova et al. 2008]. Moreover, Haak [2003] reported that trees on the dwarfing rootstocks yielded one third lesser than the trees on the medium rootstock MM106. In this study, higher yield was obtained from the scions grafted on MM106 rootstock but the ratio in yield increase was not as high as reported by Haak [2003]. In fact, many researchers have reported that Golden Delicious and Granny Smith are productive cultivars [Seferoğlu et al. 2006, Soylu et al. 2003]. Higher yield per cm<sup>2</sup> trunk was obtained from Golden Delicious (0.72 kg cm<sup>-2</sup>) and Granny Smith (0.62 kg cm<sup>-2</sup>) but there was no statistically significant differences found between rootstocks (tab. 3). Soylu et al. [2003] reported that 7 year old Granny Smith on MM106 rootstock produce 26.4 kg tree<sup>-1</sup> and 0.39 kg cm<sup>-2</sup> trunk in Marmara region of Turkey. Seferoglu et al. [2006] reported a cumulative yield as 12.7 kg tree<sup>-1</sup> for 2001 and 2002 years and a yield of 0.33 kg cm<sup>-2</sup> trunk in Aegean region of Turkey. The average yield obtained from a tree was smaller than those of previous studies, but yield per cm<sup>2</sup> trunk was higher in this study (tab. 3).

**Table 3.** Effect of apple cultivars and rootstocks on yield parameters under subtropical ecological conditions (means of 2013–2015)

Variable	Characteristics						
	Trunk circumference (cm)	TCSA* (cm <sup>2</sup> )	Number of fruit/tree	kg tree <sup>-1</sup>	kg cm <sup>-2</sup>	t ha <sup>-1</sup>	
Cultivar	Granny Smith	44.92 c	16.42 b	56.01 b	9.71 a	0.62 a	20.62 a
	Golden Delicious	44.19 c	16.07 b	64.68 a	9.78 a	0.72 a	21.96 a
	Starking Delicious	52.23 a	21.57 a	44.00 c	5.76 b	0.27 b	11.83 b
	Vista Bella	46.31 bc	17.35 b	45.92 c	4.64 bc	0.25 b	9.68 b
	Jerseymac	51.12 ab	21.41 a	42.60 c	4.21 c	0.21 b	9.21 b
Rootstock	M9	45.63 b	16.98 b	45.17 b	5.82 b	0.40 a	16.17 a
	MM106	49.87 a	20.15 a	56.11 a	7.89 a	0.43 a	13.15 b
LSD cultivar	5.87	3.81	7.21	1.45	0.21	3.14	
LSD rootstock	3.71	2.41	4.56	0.92	0.13	1.98	

The letters in differ columns shown statistically significant at  $p < 0.05$

\* Trunk Cross Sectional Area

**Table 4.** Effect of apple cultivars and rootstocks on yield parameters under subtropical ecological conditions (cumulative data of 2013–2015)

Variable	Characteristics			
	kg tree <sup>-1</sup>	kg cm <sup>-2</sup>	t ha <sup>-1</sup>	
Cultivar	Granny Smith	29.12 a	1.85 a	62.03 a
	Golden Delicious	28.72 ab	2.08 a	69.05 a
	Starking Delicious	22.35 b	1.30 b	50.35 a
	Vista Bella	13.91 c	0.76 c	27.08 b
	Jerseymac	12.61 c	0.63 c	25.15 b
Rootstock	M9	19.49 a	1.37 a	54.80 a
	MM106	23.20 a	1.28 a	38.66 b
LSD cultivar	6.70	0.46	18.75	
LSD rootstock	4.24	0.29	11.86	

Explanations as in Table 3

Higher yield for per hectare was harvested from the Golden Delicious (21.96 t ha<sup>-1</sup>) and Granny Smith (20.62 t ha<sup>-1</sup>) on both rootstocks. Average yield of the cultivars on M9 (16.17 t ha<sup>-1</sup>) was significantly higher than that of MM106 (13.15 t ha<sup>-1</sup>). This finding shared similarities with the reports of many researches on same the rootstocks [Dodengeh et al. 2012, Ozongun et al. 2016].

Granny Smith, Golden Delicious, and Starking Delicious reached higher cumulative yield parameters whereas it was lower in summer apple cultivars. Cumulative yield parameters such as yield per tree and yield for per cross sectional area were not found statistically significant between rootstocks; however, the cumulative yield per hectare in M9 (54.80 t ha<sup>-1</sup>) was higher than MM106 (38.66 t ha<sup>-1</sup>) (tab. 4).

The rootstocks did not have any effect on the fruit weight, fruit width, fruit length, flesh firmness, acidity and pH except for TSS in all the tested cultivars. The highest fruit weight, width and length values were recorded in Granny Smith whereas the lowest fruit size was detected in the Jersey mac cultivar. Ozturk and Ozturk [2016] indicated that fruit weight is 122.2 g for Golden Delicious, 163.6 g for Granny Smith, and 112.3 g for Jersey mac on MM106 (tab. 5).

The TTS content of the cultivars was the highest in M9 (13.75%) compared with MM106 (12.50%). The values of flesh firmness were the highest for Granny Smith and Golden Delicious cultivars 38.64 and 38.44 N, respectively (tab. 6). Fallahi et al. [2002] showed that fruit firmness of apple cultivars is not varied based on the rootstocks. Golden Delicious and Starking Delicious cultivars had the highest TTS contents with 14.83 and 14.58%, respectively while the acidity values were lowest in the cultivars. Ozturk

**Table 5.** Effect of apple cultivars and rootstocks on the characteristics of fruit quality (means of 2013–2015)

Variable	Fruit weight (g)	Fruit width (mm)	Fruit length (mm)
Cultivar	Granny Smith	193.10 a	76.28 a
	Golden Delicious	152.10 b	69.70 ab
	Starking Delicious	131.07 b	66.14 b
	Vista Bella	103.79 c	63.73 b
	Jerseymac	98.06 c	52.76 c
Rootstock	M9	135.35 a	64.50 a
	MM106	135.90 a	66.95 a
LSD cultivar	23.71	9.10	7.63
LSD rootstock	15.00	5.76	4.83

Explanations as in Table 3

**Table 6.** Effect of apple cultivars and rootstocks on the characteristics of fruit quality (means of 2013–2015)

Variable	Flesh firmness (N)	Number of seeds	TSS (%)	pH	Acidity (%)	
Cultivar	Granny Smith	38.64 a	8.04 a	13.17 ab	3.14 c	1.27 a
	Golden Delicious	38.44 a	8.40 a	14.83 a	3.46 ab	0.52 c
	Starking Delicious	33.14 b	6.35 b	14.58 a	3.67 a	0.49 c
	Vista Bella	35.99 ab	8.30 a	11.67 bc	3.19 c	1.09 b
	Jerseymac	23.24 c	6.94 b	11.38 c	3.30 bc	0.95 b
Rootstock	M9	34.03 a	7.66 a	13.75 a	3.41 a	0.82 a
	MM106	33.73 a	7.54 a	12.50 b	3.29 a	0.91 a
LSD cultivar	4.02	1.09	1.66	0.21	0.17	
LSD rootstock	2.55	0.69	1.05	0.13	0.11	

Explanations as in Table 3

**Table 7.** Effect of apple cultivars and rootstocks on the characteristics of fruit skin color (means of 2013–2015)

Variable	L	a	b	C	H	
Cultivar	Granny Smith	64.03 ab	-20.36 b	40.13 a	45.04 ab	116.91 a
	Golden Delicious	72.27 a	-18.01 b	45.41 a	49.03 a	111.79 a
	Starking Delicious	58.18 bc	8.77 a	32.22 b	36.22 bc	73.99 b
	Vista Bella	46.84 d	8.76 a	22.16 c	28.90 c	61.66 c
	Jerseymac	50.34 cd	14.64 a	18.27 c	29.98 c	49.24 d
Rootstock	M9	53.60 b	-1.81 a	27.81 b	33.10 b	79.70 b
	MM106	63.06 a	-0.67 a	35.47 a	42.57 a	85.73 a
LSD cultivar	10.06	7.47	6.87	10.26	8.61	
LSD rootstock	6.36	4.73	4.34	6.49	5.45	

Explanations as in Table 3

and Ozturk [2016] indicated that TSS content is 13.00% for Golden Delicious, 11.37% for Granny Smith, and 12.80% for Jerseymac on MM106. The TSS content was also affected by rootstocks, and the cultivars had the more TSS content on M9 (13.75%) in this study. The results of this study showed the parallelism with the findings of Fallahi et al. [2002] that apple cultivars have more TSS content on M9 rootstocks. Starking Delicious had the highest pH. Higher number of seeds was detected in Golden Delicious, Vista Bella and Granny Smith (tab. 6).

The color of fruit skin of apple cultivars significantly differed depending on cultivar and rootstocks (tab. 7). In general, fruit species, lower L, C and  $h^\circ$  values are associated with darker fruit skin color whereas higher values of these variables consists of fruit skin lighter color [Caliskan et al. 2012]. Golden Delicious had the lightest fruits with the high L value (72.27). The fruit skin  $a^*$  value, which indicates red color, was positive for Jerseymac (14.64), Starking Delicious (8.77), and Vista Bella (8.76) whilst the value was negative (green color) for Granny Smith (-20.36) and Golden Delicious (-18.01). Golden Delicious with the highest  $b^*$  value (45.41) had the yellow fruit skin color. Vista Bella and Jerseymac cultivars had the darkest skin color with lower L, C and  $h^\circ$  values. In addition, the cultivars were the darkest on M9 which had lower L, C and  $h^\circ$  skin color values (tab. 7). The result revealed that the

fruits received more light and the accumulation of anthocyanins decrease the growth. Yıldırım et al. [2016] indicated that less apple load results in increased more red-colored apples. In addition, Miller and Racsko [2011] assessed that there is a tendency to have poorer fruit quality with increasing vigor of the rootstocks, except flesh firmness.

## CONCLUSIONS

Apple is most important of the deciduous tree fruits in terms of production. In the past it was generally regarded as a crop of the temperate zones but is increasingly cultivated under subtropical conditions. This has been made possible by selection of early cultivars and rootstocks and by both technological innovations and modification to standard temperate zone practices.

This study revealed that summer apple cultivars such as Vista Bella and Jerseymac grafted on M9 and MM106 rootstocks, respectively, have higher economic potential based on precocity in the subtropical ecology. However, winter apple cultivars have some risks such as insufficiency of chilling requirement and sunburn on the fruit skin in the subtropical ecological conditions. Based on our result in this study, we can conclude that Vista Bella and Jerseymac are promising cultivars for the precocity apple growing in the subtropical ecology.

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