

## Growth Performance of 'Granny Smith' and 'Fuji' Cultivars Grafted onto Dwarf Rootstocks: a Preliminary Study in Eastern Anatolia

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### Abstract

This study was carried out to determine the growth performance of 'Granny Smith' and 'Fuji' apple varieties, which are widely grown in Turkey, grafted to dwarf rootstocks within their initial two years under continental ecological conditions of the Van Region in East Anatolia. In the first year, the vegetative characters of the cultivars were measured, whereas the yield and the growth rate were both determined in the second year. The yields of 'Granny Smith' and 'Fuji' varieties were 2.38 and 3.88 kg, with average fruit weights of 173.71 g and 136.76 g, respectively. The concentrations of soluble solids, an important quality attribute, were 11.2% and 12.9% for 'Granny Smith' and 'Fuji', respectively. Titratable acidity, which indicates the maturity of the fruit and specifies the market suitability, was found to be 0.37% in 'Granny Smith' and 0.52% in 'Fuji'. Although some properties differed between these cultivars, the firmness of both cultivars was the same, with a value of 6.6 lb. Although both varieties have a double sigmoid vegetative growth, 'Granny Smith's vegetative growth was relatively better than that of 'Fuji', whereas 'Fuji' had a higher productivity. However, for precise evaluation of yields, the period of economical production is required. Preliminary results of morphological, phenological, and pomological tests showed that the varieties 'Granny Smith' and 'Fuji' grafted onto dwarf rootstocks have a potential for increased production in the Van region of Eastern Turkey.

**Keywords:** Dwarf rootstock, 'Fuji', 'Granny Smith', Lake Van

### Introduction

The global size of apple orchards is 5.6 m/ha, with a production of 57 million tons and average productivity of 100.601 tons/ha. China, USA, Turkey, France, and Iran are the leading apple producers, contributing 55% of the total production. Turkey, with a proportion of 4.4%, ranks third in production, and its productivity (230.203 kg/ha) is more than the global average productivity. However, it is still in the 13<sup>th</sup> position in production, which is led by New Zealand with 380.473 kg/ha. The high yield in apple production is facilitated by cultivation of dwarf varieties, which lowers the maintenance costs due to pruning, harvesting, and applying pesticides and herbicides, in addition to increasing the nutrient uptake of roots (DPT, 2006). Moreover, dwarf apple trees come into bearing 2-3 years after planting, and therefore provide an income more rapidly than standard trees (Walsh *et al.*, 1996). Thus, apple is a promising commercial crop, particularly in regions with low income and fragmented lands.

Apple orchard systems have undergone tremendous changes over the past 60 years; they have transitioned from traditional production systems established with large trees in wide spacing arrangements to high-density orchards with smaller closely spaced trees (Robinson, 2004). In Turkey, dwarf apple cultivation has become widespread over the past two decades and has become an important

fruit in the country, with a production of approximately 2,550,000 tons/year, which is a 22% increase since the 1980s (FAO, 2007).

'Granny Smith' and 'Fuji' are common apple varieties in Turkey. The former has an average fruit weight of 160 g (Karlıdağ *et al.*, 2007), whereas the latter has a weight of 220 g (Motosugi *et al.*, 1995). Although seasonal variations and crop-management strategies cause great variations in the soluble solid concentration (SSC) in apple, the average concentration varies from 17% to 19% in 'Fuji' (Kupferman, 1992) and from 11% to 13% for 'Granny Smith' (Saftner *et al.*, 2005).

Apple can be cultivated in several regions of Turkey; however, research on the potential for dwarf apple production in Eastern Anatolia, which may provide high-income opportunities to locals, is insufficient (Küden, 1998). The Eastern Anatolia region of Turkey, particularly Lake Van-with its favorable climatic (cold weather, high intensity of sunlight) and soil (high organic matter and cation-exchange capacity) conditions (Akça *et al.*, 2008) is a notable zone for production of dwarf apples. Traditional fruit cultivation is common in the region; however, due to modern cultivation techniques, the productivity and production are low (Oğuz and Aşkın, 1993). Because the goal of modern high-density orchard systems is to achieve high yield at early tree age (Yıldırım and Kankaya, 2004), studies on dwarf cultivars in the Lake Van Region is crucial for

increasing cropping efficiency. The most important reason for choosing these cultivars is their intense growth values all over the world, and especially in Turkey, in the past few years. In this study, we determine the properties indicating the growth performance of both 'Granny Smith' and 'Fuji' cultivars grafted onto dwarf rootstocks in the Van region.

## Materials and methods

This study was undertaken in the Lake Van region of Eastern Turkey (Fig. 1) in 2007-2008 on cultivars of 'Granny Smith' and 'Fuji' grafted onto M26 and M9 rootstocks, respectively. The study site has an altitude of 1675 m a.s.l., with 377 mm precipitation and a continental cli-

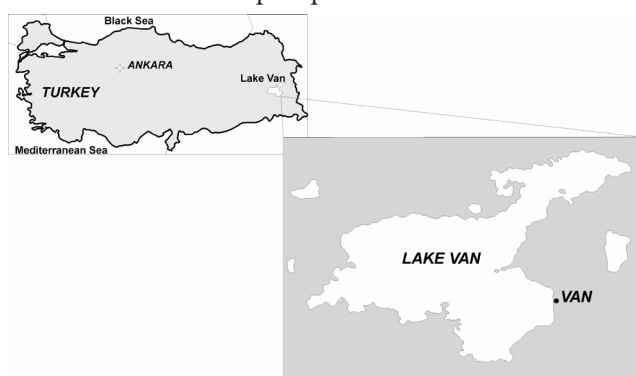


Fig. 1. Location of the study site

mate.

The saplings were planted in the spring of 2007. In the first year, the vegetative growth parameters of 30 trees were determined by measuring sapling height, stem diameter, and shoot length at 15-day intervals. The date of blooming was based on the flowering of 70-80% of the total flower buds (Oguz and Aşkın, 1993).

The height of the sapling is the distance from the budding point to the highest point of the sapling. The stem diameter is measured 10 cm above the bud eye by 0.01-cm sensitive calipers. The shoot length of each tree is measured at three shoots located at different sides of the tree (Robinson, 2004).

The measurements in the second year, undertaken at 30 trees of each cultivar, involved determination of the start of blooming, full blooming, and production, whereas the fruit properties of diameter, length, SSC, titratable acidity (TA), and pulp hardness (PH) are determined for 10 trees of each variety (Jolly and North, 1982)

The cultivars are compared by analysis of variance, and the means are differentiated using the Duncan's multiple-range tests for each variety.

## Results

The stem diameter of 'Granny Smith' increased from 12.57 mm to 21.35 mm during the first year, whereas that of the 'Fuji' cultivar increased from 11.65 mm to 19.66 mm within the same period (Tab. 1). Both cultivars had a regular growth rate until the 15<sup>th</sup> of July 2007; the development halted from the 15<sup>th</sup> of July to the 30<sup>th</sup> of July 2007 and resumed after 30<sup>th</sup> of July.

The stem growth for both cultivars in the second year showed a sigmoid growth, with a relatively slow phase in Early Spring, an increase in Mid Summer, and a retarded phase in the early Fall of 2008 (Tab. 2); with a total growth of 39.38 cm for 'Granny Smith' and 36.42 cm for 'Fuji'. The growth of both cultivars showed a linear development, with mean increases of 43.75 cm for 'Granny Smith' (from 79.51 cm to 123.26 cm) and 40.34 cm for 'Fuji' (from 73.32 cm at the initial stage to 113.66 at the end of the season) in 2007 (Tab. 3).

The results obtained in this study are in accordance with the studies undertaken by Kadan and Yarılgaç (2005), who determined the sapling height as 89.17 and 109.75 cm for other cultivars in Eastern Anatolia. Tekintaş *et al.* (1999) found the sapling height for local varieties in the Lake Van region in the range of 60-84 cm. Other authors, however, report significant differences in the growth rates for 'S. Delicious', 'G. Delicious', and 'S. Spur Golden' saplings, with heights of 181.3, 190.4, and 200.5 cm, respectively, in the mild climates of Bursa region, Western Turkey (Soylu and Başyigit, 1991).

In 2008, the growth rate of the trees was relatively high, particularly in June and July (Tab. 4). 'Granny Smith'

Tab. 1. Comparison of cultivars in terms of their body diameter in 2007

Date of measurement	Cultivars		'Granny Smith'		'Fuji'		P
	'Granny Smith'	'Fuji'	least	most	least	most	
30.05.2007	12.57 ± 0.24a	11.65 ± 0.33b	7.20	18.5	7.00	17.20	*
15.06.2007	13.66 ± 0.25a	12.05 ± 0.32b	8.00	20.00	7.20	18.00	***
30.06.2007	14.88 ± 0.27a	13.44 ± 0.35b	8.80	23.30	8.00	20.10	**
15.07.2007	16.02 ± 0.26a	14.61 ± 0.35b	10.10	23.90	9.90	20.90	**
29.07.2007	16.02 ± 0.26a	14.61 ± 0.35b	10.10	23.90	9.90	20.90	**
15.08.2007	18.66 ± 0.27a	17.22 ± 0.35b	13.40	26.00	12.30	23.70	**
29.08.2007	19.96 ± 0.27a	18.46 ± 0.35b	14.20	27.30	13.50	25.50	**
14.09.2007	21.35 ± 0.31a	19.66 ± 0.40b	15.30	28.50	14.60	27.30	**

Tab. 2. Comparison of cultivars in terms of their body diameter in 2008

Date of measurement	cultivars		'Granny Smith'		'Fuji'		P
	'Granny Smith'	'Fuji'					
	AVRG ± SE	AVRG ± SE	least	most	least	most	
30.05.2008	22.72 ± 0.32a	21.01 ± 0.42b	7.20	18.5	7.00	17.20	*
15.06.2008	24.88 ± 0.35a	23.01 ± 0.46b	8.00	20.00	7.20	18.00	*
30.06.2008	27.37 ± 0.38a	25.31 ± 0.51b	8.80	23.30	8.00	20.10	*
15.07.2008	30.17 ± 0.42a	27.90 ± 0.56b	10.10	23.90	9.90	20.90	*
29.07.2008	34.98 ± 0.49a	32.36 ± 0.65b	10.10	23.90	9.90	20.90	*
15.08.2008	36.54 ± 0.51a	33.80 ± 0.68b	13.40	26.00	12.30	23.70	*
29.08.2008	38.07 ± 0.53a	35.21 ± 0.71b	14.20	27.30	13.50	25.50	*
14.09.2008	39.38 ± 0.55a	36.42 ± 0.73b	15.30	28.50	14.60	27.30	*

\* P &lt; 0.05; \*\* P &lt; 0.01; \*\*\* P &lt; 0.001 (The difference between the letters in each line is vital)

Tab. 3. Comparison of cultivars in terms of their height in 2007

Date of measurement	cultivars		'Granny Smith'		'Fuji'		P
	'Granny Smith'	'Fuji'					
	AVRG ± SE	AVRG ± SE	least	most	least	most	
30.05.2007	79.51 ± 0.83a	73.32 ± 1.14b	56.00	103.00	56.00	93.00	***
15.06.2007	86.01 ± 0.90a	79.36 ± 1.22b	61.00	111.00	61.00	100.00	***
30.06.2007	92.74 ± 0.97a	85.48 ± 1.33b	65.00	120.00	65.00	108.00	***
15.07.2007	99.68 ± 1.04a	91.91 ± 1.42b	70.00	129.00	70.00	116.00	***
29.07.2007	105.85 ± 1.11a	97.63 ± 1.51b	75.00	137.00	75.00	123.00	***
15.08.2007	112.12 ± 1.17a	103.41 ± 1.61b	79.00	145.00	79.00	130.00	***
29.08.2007	118.35 ± 1.24a	109.14 ± 1.70b	83.00	153.00	83.00	138.00	***
14.09.2007	123.26 ± 1.29a	113.66 ± 1.76b	87.00	159.00	87.00	143.00	***

\* P &lt; 0.05; \*\* P &lt; 0.01; \*\*\* P &lt; 0.001 (The difference between the letters in each line is vital)

Tab. 4 Comparison of cultivars in terms of their heights in 2008

Date of measurement	Cultivars		'Granny Smith'		'Fuji'		P
	'Granny Smith'	'Fuji'					
	AVRG ± SE	AVRG ± SE	least	most	least	most	
30.05.2008	131.41 ± 1.37	121.27 ± 1.88	93.00	170.00	93.00	153.00	***
15.06.2008	141.90 ± 1.48	130.84 ± 2.03	100.00	183.00	100.00	165.00	***
30.06.2008	155.42 ± 1.62	143.38 ± 2.22	110.00	201.00	110.00	181.00	***
15.07.2008	170.21 ± 1.78	156.96 ± 2.44	120.00	220.00	120.00	198.00	***
29.07.2008	181.60 ± 1.90	167.43 ± 2.60	128.00	235.00	128.00	211.00	***
15.08.2008	189.67 ± 1.98	174.89 ± 2.72	134.00	245.00	134.00	221.00	***
29.08.2008	197.59 ± 2.06	182.14 ± 2.84	139.00	255.00	139.00	230.00	***
14.09.2008	204.39 ± 2.13	188.48 ± 2.93	144.00	264.00	144.00	238.00	***

\* P &lt; 0.05; \*\* P &lt; 0.01; \*\*\* P &lt; 0.001 (The difference between the letters in each line is vital)

Tab. 5. Comparison of cultivars in terms of their shoot lengths in 2007

Date of measurement	Cultivars		'Granny Smith'		'Fuji'		P
	'Granny Smith'	'Fuji'					
	AVRG ± SE	AVRG ± SE	least	most	least	most	
30.05.2007	6.18 ± 0.24a	5.58 ± 0.15a	3.57	30.05	2.67	8.10	ns
15.06.2007	6.64 ± 0.14a	6.12 ± 0.17b	3.93	15.06	2.97	8.87	*
30.06.2007	6.77 ± 0.24a	6.75 ± 0.19a	3.93	30.06	3.23	9.80	ns
15.07.2007	7.67 ± 0.15a	7.34 ± 0.20a	4.53	15.07	3.53	10.67	ns
29.07.2007	8.30 ± 0.24a	7.83 ± 0.22a	4.83	30.07	3.77	11.37	ns
15.08.2007	8.52 ± 0.16a	8.18 ± 0.23a	5.03	15.08	3.93	11.90	ns
29.08.2005	8.75 ± 0.16a	8.40 ± 0.23a	5.20	15.09	4.07	12.20	ns
14.9.2007	8.45 ± 0.15a	8.92 ± 0.25a	5.02	30.05	4.30	12.90	ns

\* P &lt; 0.05; \*\* P &lt; 0.01; \*\*\* P &lt; 0.001; ns: non significant (The difference between the letters in each line is vital)

reached a height of 204.39 cm and 'Fuji', 188.48 cm (Tab. 4). The shoot lengths of 'Granny Smith' and 'Fuji' were measured at 15-day intervals for determining the annual and the seasonal growth rates. 'Granny Smith' had a mean shoot lengths of 6.18 and 8.45 cm, when measured on the 30<sup>th</sup> of May 2007 and in early fall, respectively (Tab. 5). The shoot length of 'Fuji' reached 8.45 cm from an initial length of 6.18 cm (Tab. 5).

In 2008, 'Granny Smith' showed relatively slow shoot development until the 15<sup>th</sup> of June, which accelerated thereafter; on the contrary, for the 'Fuji' cultivar, shoot development was the maximum between the 15<sup>th</sup> and 30<sup>th</sup> of July (Tab. 6). The seasonal differences in the shoot growth between the two years are most probably caused by climatic differences.

The major advantage of the dwarf rootstock is the early setting of fruit in the grafted cultivar (Küden *et al.*, 1993). In the present study, the cultivars bore fruits in the second year, yielding 2.37 kg/tree for 'Granny Smith' and 3.88 kg/

tree for 'Fuji' (Tab. 7), with average fruit weights of 173.71 and 139.76 g for the two cultivars, respectively (Tab. 8).

The mean pomological characteristics of the cultivars were given in Tab. 9. For 'Granny Smith' and 'Fuji', the fruit diameters were 75.8 and 63.5 mm, and the average lengths were 63.6 and 57.1, respectively (Tab. 1). The properties of the fruits were similar to the previous findings of Kaşka and Küden (1994), and Kankaya and Özyiğit (1998). The pH for both cultivars was 6.6 lb, and the SSC were 11.2% for 'Granny Smith' and 12.9% for 'Fuji' (Tab. 9).

The TA contents were 37% and 52% for 'Granny Smith' and 'Fuji', respectively, which are within the standard values of Cripps *et al.* (1993), Oğuz and Aşkın (1993), and Karlıdağ *et al.* (2007).

Blooming of both cultivars was found to occur close to each other. The first blooming date for 'Granny Smith' was 13<sup>th</sup> of May 2008, and full blooming was achieved within 7 days. The 'Fuji' cultivar first effloresced on the 12<sup>th</sup> of May 2008 and, similar to 'Granny Smith', full efflorescence was reached on the 19<sup>th</sup> of May 2008.

Tab. 6. Comparison of cultivars in terms of their shoot lengths in 2008

Period	Cultivars		'Granny Smith'		'Fuji'		P
	'Granny Smith'	'Fuji'	least	most	least	most	
30.05.2008	4.06 ± 0.10a	5.14 ± 0.16b	3.74	8.89	3.20	8.50	***
15.06.2008	4.27 ± 0.09b	5.62 ± 0.18a	3.31	7.63	3.07	9.30	*
30.06.2008	5.11 ± 0.06b	6.20 ± 0.20a	2.69	7.45	3.37	10.27	**
15.07.200	6.15 ± 0.08b	6.74 ± 0.22a	3.25	7.06	3.67	11.20	***
29.07.2008	6.84 ± 0.08b	8.16 ± 0.23a	3.08	6.97	3.90	11.87	**
15.08.2008	7.70 ± 0.07b	8.40 ± 0.24a	3.01	6.93	4.03	12.27	***
29.08.2008	7.90 ± 0.08b	8.72 ± 0.25a	3.11	7.76	4.20	12.80	***
14.9.2008	8.81 ± 0.08b	9.13 ± 0.26a	3.07	5.84	4.43	13.37	***

\* P < 0.05; \*\* P < 0.01; \*\*\* P < 0.001 (The difference between the letters in each line is vital)

Tab. 7. Some pomological properties of the 'Granny Smith' cultivar in 2008

Fruit Weight (gr)	Fruit diameter (mm)	Fruit Length (mm)	TA	SSC (%)	Productivity tree/kg	PH (lb)
157	71.52	57.42	0.34	10.05	2.33	5.80
159	74.59	56.99	0.35	11.05	2.45	6.00
167	75.30	62.73	0.35	11.05	2.21	6.50
172	76.66	64.41	0.38	11.05	2.22	6.60
178	76.85	66.92	0.40	11.09	2.33	7.10
185	77.07	67.55	0.40	12.00	2.08	7.10
198	78.61	68.95	0.40	12.01	2.03	7.30

Tab. 8. Some pomological properties of the 'Fuji' cultivar in 2008

Fruit Weight (gr)	Fruit diameter (mm)	Fruit Length (mm)	TA	SSC (%)	Productivity tree/kg	PH (lb)
107.00	55.18	52.08	0.40	11.05	3.666	5.60
112.05	61.09	52.12	0.40	12.05	3.956	5.70
117.00	62.00	54.39	0.41	12.08	3.646	6.05
117.09	62.43	54.62	0.51	13.00	3.956	6.60
139.07	63.09	57.74	0.53	14.00	3.611	7.00
187.07	66.66	64.25	0.69	14.04	4.105	7.60
199.05	74.37	64.26	0.70	14.05	4.255	7.70

Tab. 9. Some fruit characteristics of 'Granny Smith' and 'Fuji' cultivars in 2008

Cultivar	Fruit diameter (mm)	Fruit Length (mm)	TA (%)	SSC (%)	PH (lib)	First Blooming Date	Full Blooming Date
'Granny Smith'	75.8	63.6	0.37	11.2	6.6	13.05.2008	21.05.2008
'Fuji'	63.5	57.1	0.52	12.9	6.6	12.05.2008	19.05.2008

## Discussion

The preference for grafting cultivars onto dwarf rootstocks for apple cultivation is aimed at the production of more flowers and fruits. In addition, saplings grafted onto dwarf rootstocks produce fruits approximately in the second year, which is 4 or 5 years earlier than the original rootstock. The annual production per hectare in the 5<sup>th</sup> year is 250 tons, which is five or six times higher than that in the traditional varieties. Thus, cultivation of dwarf apples has several benefits for producers. Turkey being the original source of apple has sites suitable for apple production; however, studies in Eastern Turkey, particularly in the Lake Van region, is not sufficient. Our preliminary study showed that 'Granny Smith' and 'Fuji' cultivars, when grafted onto M9 and M26 rootstocks, respectively, have high economic potential in the Van region, in spite of the region having harsh topographic and climatic conditions. Shifting from traditional varieties to dwarf ones may also increase the income of local farmers, who are struggling due to low incomes from traditional cultivars. Based on all the vegetative growth phases, we can conclude that 'Granny Smith's' growth rate is relatively higher than that of 'Fuji', whereas 'Fuji's' production is better than that of 'Granny Smith'. However, further studies are required for the precise evaluation of the productivity of both varieties when the trees are in the full-production stage.

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