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Assessment of growth behaviour, yield, and quality parameters of some olive (*Olea europaea*) cultivars in Turkey

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Abstract Olive (*Olea europaea*) is one of the oldest cultivated species in the Mediterranean basin and it is widespread throughout the Mediterranean region. In this study, we determined several phenological, morphological, and pomological characteristics of a number of olive cultivars when grown in Hatay province in the eastern Mediterranean region of Turkey. The 21 cultivars examined had their origins in Italy, Spain, Tunisia, and Turkey. The earliest flowering was observed in 'Gemlik' and 'Silifke yağlık' on 4 May whereas the latest flowering was in 'Memeli', 'Domat', and 'Savrani' on 10 May. 'Gemlik' and 'Manzanilla de Sevilla' produced the highest cumulative yield over a 4-year period. The largest fruit were from 'Ascolana', averaging 6.72 g whereas 'Kilis yağlık' (2.05 g), 'Nizip yağlık' (2.33 g), and 'Meski' (2.43 g) had the smallest fruit. The flesh comprised the highest fraction of total fruit weight in 'Manzanilla de Sevilla' (86.4%), 'Gemlik' (86.4%), 'Edincik su' (86.3%), 'Hojiblanca' (86.1%), and 'Halhalı' (86.0%). The highest oil content was in 'Kilis yağlık' (31.2%) and 'Savrani' (29.3%). Based on our results, 'Gemlik' and 'Manzanilla de Sevilla' are suggested for table olive production in the Hatay region whereas 'Memecik', 'Kilis yağlık', and 'Sarı ulak' are the most suitable for oil production.

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INTRODUCTION

Olive (*Olea europaea* L.) was one of the first fruit tree species domesticated. Current world cultivation extends over 8.5 million ha and produces 14 633 440 metric t of olives per year (Anon. 2005). Ninety-seven percent of this production is in the Mediterranean basin. Olives are widely cultivated throughout the Mediterranean basin and represent one of the most important crops there. The olive fruit is a drupe that is used both for its oil and also as a table fruit. Olive oil is a major component of the traditional Mediterranean diet and world consumption is increasing steadily as it is produced without refinement and is high in healthy, unsaturated fatty acids and antioxidants with claimed preventative and curative effects on cardiovascular disease and cancer (Lipworth et al. 1997; Visioli et al. 1998; Visioli & Galli 1998). As in many other countries, new olive orchards are being established in Turkey to supply the increasing world demand for olive oil and table olive.

Because of its favourable ecological conditions, olive has been cultivated for many years in southern Turkey's Hatay province, located in the eastern Mediterranean. In this region, the local olive cultivars 'Kargaburnu', 'Halhalı', 'Savrani', and 'Sarı haşebi' are traditionally cultivated for oil production (Ayanoğlu et al. 2000). Recently, however, 'Gemlik' has been planted more commonly with c. 6 million nursery trees having been planted into new orchards between 1996 and 2006 (Anon. 2007).

Olives are widespread in many ecological regions in Turkey. In addition to the table and oil olive cultivars, there are also wild-type olives that have no economic value. It is well known that ecological and cultivation conditions have significant effects on both yield and quality of olives (Cimato et al. 1990; Bignami et al. 1994; Michelakis 2002). Therefore, before introducing any new cultivar to a region, its performance in the region should first

be investigated. Selection of the best performing cultivars has the potential to be advantageous for many aspects of production. For example, the use of a number of different table and oil cultivars having different characteristics can extend the harvest period. This would allow quality losses to be reduced as a result of fewer processing delays occasioned by overloading of limited post-harvest facilities.

The objective of this study was to investigate the performance, in the Hatay region, of a number of olive cultivars, including several of foreign origin in a comparison with a locally-popular selection. The ultimate goal is to diversify the olive cultivars under cultivation in the Hatay region by introducing some new, superior and well-adapted cultivars having high yields and high fruit quality.

MATERIALS AND METHODS

The trials were carried out between 2001 and 2004 at the experimental farm of Kırıkhan Fruit Production Station (36°18′E, 36°27′N; 103 m) in Hatay province located in the eastern Mediterranean region in the south of Turkey. Meteorological data for Kırıkhan county are presented in Table 1.

Cultivars from Spain ('Manzanilla de Sevilla' and 'Hojiblanca'), Italy ('Ascolana'), Tunisia ('Meski'), and Turkey ('Ayvalık', 'Memecik', 'Memeli', 'Domat', 'İzmir sofralık', 'Sarı yaprak', 'Edincik su', 'Uslu', 'Gemlik', 'Samanlı', 'Sarı ulak', 'Silifke yağlık', 'Kilis yağlık', 'Nizip yağlık', 'Halhalı', 'Savrani', and 'Sarı haşebi') were tested. The olive orchard was established with 1-year-old trees, self rooted from cuttings under mist propagation, in 1996. A randomised block design was used with six replications. The planting distance was 6 × 6 m. The soil was a clay loam with 1.5% organic matter and a pH of 7.5. The canopies were trained to a goblet shape and trees were fertilised with 300 g N plant^{-1}, 200 g P_2O_5 plant^{-1}, and 300 g K_2O plant^{-1} at the beginning of the each growing season. They were drip irrigated.

Phenological, morphological, and pomological characteristics were assessed. The flowering period was determined as the time interval between the beginning and end of flowering. Fruit maturity was determined in 100 fruit from each replicate as a "maturity index" where "green maturity" (1) = skin just changing from green to yellow, through to "black maturity" (5) = skin is black and 50% of the flesh is purple (Uceda & Frias 1975; Boskou 1996; Kaynaş et al. 2002). Fruit removal force (FRF) was determined in fruit of green and of black maturity fruits using a Chatillon dynamometer on 100 fruits from each replicate. Fruit were harvested by hand and the total yield (kg/tree) was determined at the black maturity stage. Fruit weight (g), fruit width (mm), and fruit length (mm) were recorded, and fruit shape index (length/width) was calculated. The stone was then removed and flesh and stone were weighed separately. The flesh to stone ratio (F/S)

Table 1 Meteorological data for Kırıkhan, Hatay, Turkey during the trial period.

	Month											
Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
Min. temperature (°C)												
2001	–1.1	–0.8	6.2	7.2	10.3	15.3	18.0	18.0	16.0	8.8	–2.4	–1.9
2002	–2.3	0.6	3.5	6.6	9.5	12.8	17.4	18.7	14.0	7.4	5.6	–3.2
2003	0.3	–1.6	–0.8	6.0	10.8	14.4	19.0	19.2	13.2	3.0	2.3	0.0
2004	0.1	–1.0	–0.1	5.0	9.5	13.2	17.1	18.1	11.2	2.1	2.0	0.1
Mean	–0.8	–0.7	2.2	6.2	10.0	13.9	17.8	18.5	13.6	5.3	1.8	–1.2
Max. temperature (°C)												
2001	17.7	20.8	26.7	33.8	36.4	41.0	41.6	41.0	38.2	35.8	26.0	18.2
2002	20.4	22.0	26.4	27.0	34.7	40.8	42.8	42.0	37.6	35.8	26.4	16.3
2003	19.8	15.0	22.6	28.2	36.5	38.6	40.8	40.4	39.2	33.6	27.2	18.9
2004	16.2	18.0	23.2	27.8	35.2	37.2	39.1	39.2	38.1	32.1	26.1	12.5
Mean	18.5	18.9	24.7	29.2	35.7	39.4	41.1	40.7	38.2	34.3	26.4	16.5
Total precipitation (mm)												
2001	20.4	138.9	35.0	50.5	93.1	–	–	0.6	–	44.7	45.4	182.1
2002	106.2	57.2	81.5	69.7	3.3	6.6	–	–	11.0	20.8	49.8	105.8
2003	75.7	199.3	180.5	44.2	2.2	6.0	–	–	10.2	14.8	69.9	102.6
2004	85.1	203.1	190.0	50.1	5.2	–	–	–	–	10.2	67.5	100.3
Mean	71.8	149.6	121.7	53.6	25.9	3.15	–	0.2	5.3	22.6	58.2	122.7

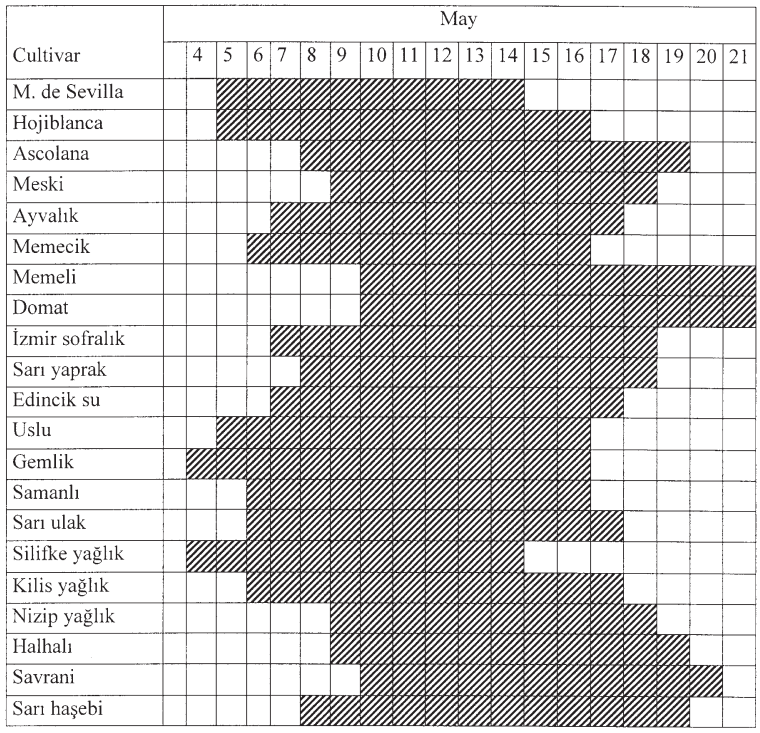


Fig. 1 Flowering period (mean of 2001–04) of several olive (*Olea europaea*) cultivars grown under Kırıkhan, Hatay, Turkey conditions.

was determined. Moisture content was determined by oven-drying at 105±1°C for 48 h. Twenty dried whole olives from each replicate were ground using a mortar and pestle, and 10 g of the paste was put into a Soxhlet cartridge. The oil was extracted with 150 ml of hexane at 70°C for 6 h. The percentage oil content was calculated on a fruit fresh weight (FFW) basis (Agar et al. 1998).

An "alternate bearing index" (ABI) was calculated between years 2001 and 2004, using the following expression (Monselise & Goldschmidt 1982):

$$\mathrm{ABI} = \frac{1}{n-1} \times \left\{ \frac{\mathrm{Ia_2 - a_1 I}}{\mathrm{a_2 + a_1}} + \frac{\mathrm{Ia_3 - a_2 I}}{\mathrm{a_3 + a_2}} + \cdots \frac{\mathrm{Ia_n - a_{n-1} I}}{\mathrm{a_n + a_{n-1}}} \right\}$$

where n = number of years, and a_1, a_2, ..., a_{n-1}, a_n = yields in the corresponding years.

Trunk diameter and canopy volume were measured in the November of each year. Trunks were marked 30 cm above the soil surface with red stain and were measured with callipers at the same point each year. Canopy volume (CV) was calculated from measurements of canopy height and spread, assuming its shape to be a prolate spheroid and thus applying the formula:

$$CV = 4/3\ \pi ab^2$$

where a is canopy height/2, and b is canopy spread/2 (Westwood 1993).

Means of the various phenological, morphological, and pomological characteristics were calculated and data were subjected to analysis of variance. Mean separations were carried out by a least significant difference (LSD) method and assessed at the 5% significance level (SAS 2005).

RESULTS

Flowering started on similar dates in 2002, 2003, and 2004 but was somewhat earlier in 2001 (Fig. 1). This promotion may be attributable to warmer temperatures and lower rainfall in 2001 (Table 1). The earliest flowering was observed in 'Gemlik' and 'Silifke yağlık' on 4 May whereas the latest flowering was observed in 'Memeli', 'Domat', and 'Savrani' on 10 May. 'Manzanilla de Sevilla' and 'Silifke yağlık' completed flowering earlier than the other cultivars on 14 May whereas 'Domat' and 'Memeli' completed flowering on 21 May. Flowering duration ranged from 10 to 13 days (Fig. 1).

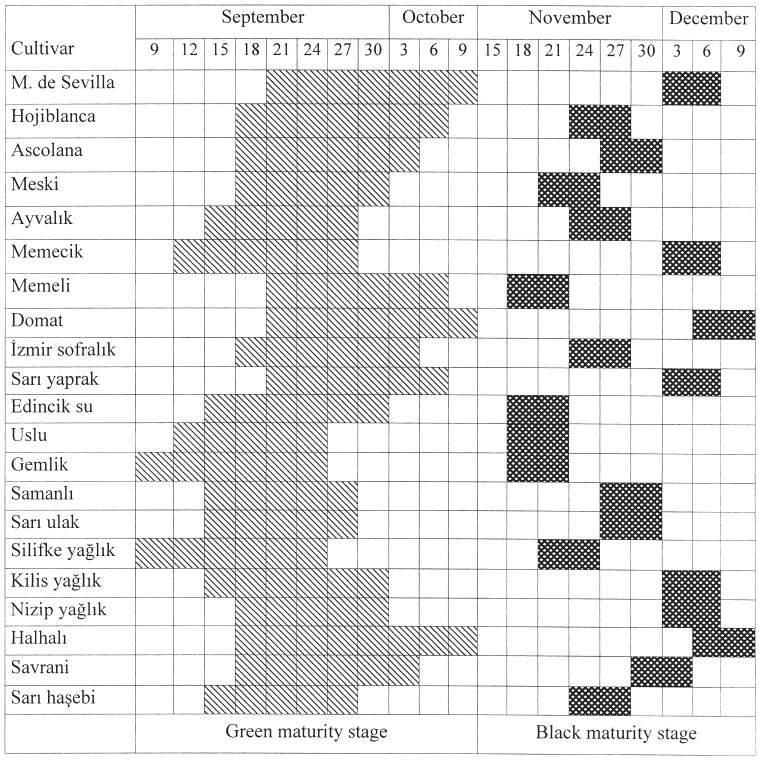


Fig. 2 Stage of green and black maturity (means of 2001–04) in several olive (*Olea europaea*) cultivars grown under Kırıkhan, Hatay, Turkey conditions.

The least number of days from full flowering to green maturity was recorded in 'Gemlik' (115 days) whereas the greatest number of days was in 'Manzanilla de Sevilla ' (129 days) (Fig. 2). The earliest green maturity was observed in 'Gemlik' and 'Silifke yağlık' on 9 September whereas the latest was in 'Manzanilla de Sevilla', 'Memeli', 'Domat', and 'Sarı Yaprak' on 21 September. 'Uslu', 'Gemlik', and 'Silifke yağlık' completed green maturity earlier than the other cultivars (24 September) whereas 'Manzanilla de Sevilla', 'Domat', and 'Halhalı' completed green maturity on 9 October. The number of days from full flowering to black maturity was 183, 184, 184, and 201 days, in 'Edincik su', 'Uslu', 'Gemlik', and 'Manzanilla de Sevilla', respectively. 'Memeli', 'Edincik su', 'Uslu', and 'Gemlik' reached black maturity on 18 November whereas 'Domat' and 'Halhalı' reached it on 6 December. The other cultivars reached black maturity between these two dates (Fig. 2).

Significant cultivar differences were found for trunk cross-section area and for canopy volume (Table 2). 'Ascolana', 'Edincik su', 'Ayvalık', 'Gemlik', and 'İzmir sofralık' had the smallest trunk cross-section areas whereas 'Memecik', 'Sarı ulak', and 'Memeli' had the largest. 'Gemlik', 'İzmir sofralık', 'Sarı yaprak', 'Savrani', and 'Edincik su' formed smaller canopies whereas 'Uslu', 'Memeli', 'Ascolana', 'Domat', and 'Hojiblanca' had larger canopies (Table 2).

Fruit yield gradually increased during the trial and reached its highest values in 2004 (Fig. 3). Although there were some fluctuations in yield between growing seasons, severe alternate bearing was not observed. This result may be explained as being the result of the application of good cultural practice such as irrigation and fertilisation. It is also known that in young olive trees, alternate bearing is not very prevalent. The highest cumulative yields over the 4 years were in 'Gemlik' (26.8 kg/tree) and 'Manzanilla de Sevilla' (25.0 kg/tree). These were followed by 'Hojiblanca' (23.2 kg/tree), 'Memecik' (23.2 kg/tree), and 'Sarı ulak' (22.3 kg/tree). The lowest cumulative yields over the 4 years were in 'Silifke yağlık' (15.6 kg/tree), 'Sarı haşebi' (15.9 kg/tree), 'Meski' (16.3 kg/tree), and 'Edincik su' (16.6 kg/tree) (Fig. 3).

The cultivars examined in this study showed different values of alternate bearing index (ABI), an important horticultural characteristic. The highest

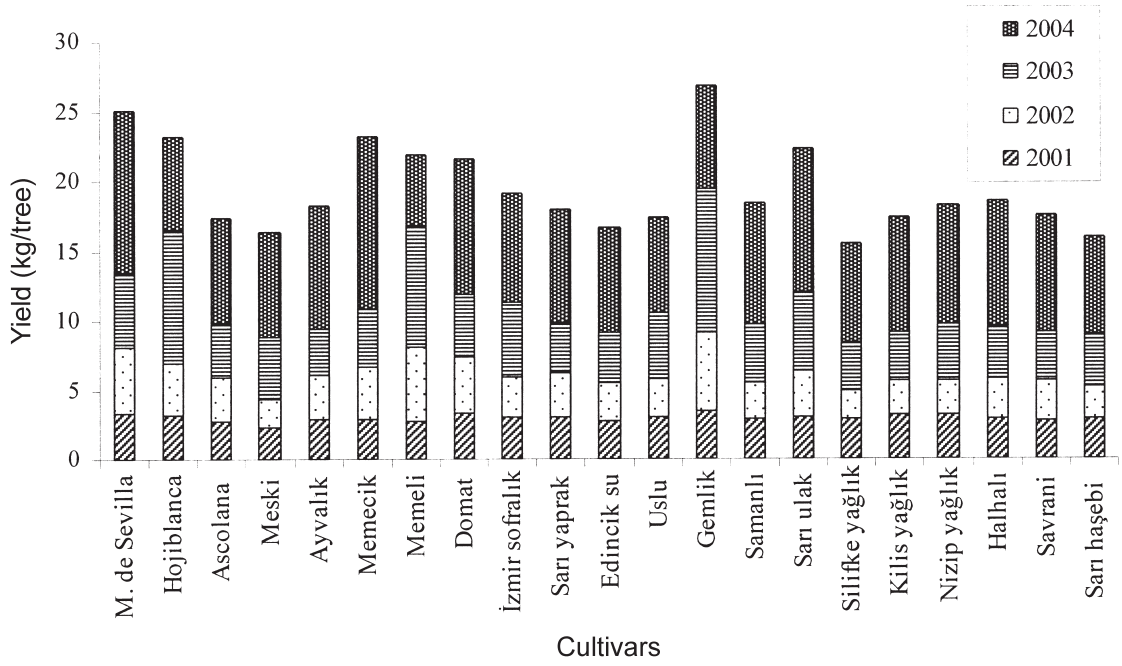


Fig. 3 Yields/cumulative yields of several olive (*Olea europaea*) cultivars grown under Kırıkhan, Hatay, Turkey conditions between 2001 and 2004.

Table 2 Trunk cross-section area and canopy volume of several olive (*Olea europaea*) cultivars grown between 2002 and 2004 under Kırıkhan, Hatay, Turkey conditions.

Cultivar	Trunk cross-section area (cm^2)			Canopy volume (m^3)		
	2002	2003	2004	2002	2003	2004
M. de Sevilla	80.3 a–d	104.7 a–c	130.7 b–e	4.8 a–d	6.4 b–d	9.6 b–d
Hojiblanca	77.0 b–f	97.7 b–f	130.7 b–e	4.7 a–d	6.8 a–c	10.1 ab
Ascolana	66.0 g	89.7 f	120.3 f	5.2 a	7.1 a	10.2 ab
Meski	74.7 b–f	98.0 b–f	135.5 a–c	4.4 cd	6.7 a–c	9.9 a–c
Ayvalık	70.2 e–g	89.0 f	122.5 ef	4.5 b–d	6.5 a–d	9.4 b–e
Memecik	86.3 a	109.8 a	139.8 a	5.2 a	7.1 a	10.0 a–c
Memeli	81.2 a–c	101.7 a–e	137.3 ab	4.5 b–d	6.8 a–c	10.3 ab
Domat	78.0 b–e	96.7 b–f	133.2 a–d	5.0 a–c	6.9 a–c	10.1 ab
İzmir sofralık	71.0 e–g	93.7 d–f	123.0 ef	4.3 d	6.3 cd	8.4 ef
Sarı yaprak	73.0 d–g	93.7 d–f	124.2 d–f	4.5 b–d	6.5 a–d	8.4 ef
Edincik su	69.7 fg	89.2 f	122.2 ef	4.5 b–d	6.4 b–d	8.5 ef
Uslu	81.0 a–d	102.0 a–d	133.0 a–d	5.1 ab	7.0 ab	10.7 a
Gemlik	72.2 e–g	92.1 ef	122.3 ef	4.3 d	6.0 d	8.0 f
Samanlı	76.7 b–f	95.3 c–f	133.0 a–d	4.6 a–d	6.4 b–d	9.4 b–e
Sarı ulak	82.3 ab	105.3 ab	137.3 ab	5.2 a	6.9 a–c	10.0 a–c
Silifke yağlık	77.8 b–e	99.8 b–e	134.8 a–c	4.4 cd	6.7 a–c	9.0 c–f
Kilis yağlık	78.0 b–e	92.4 d–f	128.0 c–f	4.4 cd	6.4 b–d	9.4 b–e
Nizip yağlık	75.7 b–f	96.5 b–f	128.2 c–f	4.4 cd	6.3 cd	8.7 d–f
Halhalı	74.2 c–f	92.5 d–f	125.2 d–f	4.6 a–d	6.5 a–d	8.6 d–f
Savrani	76.5 b–f	95.8 b–f	126.7 c–f	4.4 cd	6.3 cd	8.4 ef
Sarı haşebi	73.0 d–g	95.3 c–f	130.8 b–e	4.8 a–d	6.9 a–c	9.9 a–c
Mean	75.9	96.7	129.4	4.6	6.6	9.3
$LSD_{0.05}$	8.05	9.68	9.04	0.60	0.60	1.02

ABI values were recorded for 'Meski' (0.67), 'Silifke yağlık' (0.66), and 'Nizip yağlık' (0.66) whereas the lowest were for 'Ascolana' (0.44), 'Domat' (0.45), 'Sarı yaprak' (0.45), and 'Uslu' (0.46). ABI values recorded for 'Gemlik' and 'Manzanilla de Sevilla', the cultivars having the highest cumulative yields, were 0.52 and 0.48 respectively (Table 3).

The highest fruit removal force (FRF) at green maturity was recorded in 'Domat' (697 g), and 'Sarı yaprak' (694 g), whereas the lowest was in 'Kilis yağlık' and 'Edincik su' with 454 g and 472 g, respectively. FRF decreased significantly at the black maturity stage. This reduction in FRF was the greatest in 'Sarı yaprak' (45%) and least in 'Samanlı' and 'Kilis yağlık' (both 32%). At black maturity, the highest FRF was also found in 'Domat' (389 g), 'Sarı yaprak' (381 g), and 'Manzanilla de Sevilla' (380 g) whereas the lowest FRF was in 'Edincik su' (303 g) and 'Kilis yağlık' (309 g). At black maturity, the greatest fruit removal force/fruit weight ratios (FRF/FW) were found in from 'Nizip yağlık' (153.65), 'Kilis yağlık' (150.73), and 'Meski' (139.09) whereas the lowest were in 'Ascolana' (51.79), 'İzmir sofralık' (54.48), and 'Edincik su' (66.89) (Table 3).

Among the cultivars in this study, the heaviest fruits were harvested from 'Ascolana' (6.72 g), followed by 'İzmir sofralık' and 'Domat' with 5.91 and 5.54 g, respectively. The smallest fruits were from 'Kilis yağlık' (2.05 g), 'Nizip yağlık' (2.33 g), and 'Meski' (2.43 g) (Table 3). The highest fruit lengths and widths were measured in 'Ascolana' (27.60 and 21.31 mm, respectively) and in 'İzmir sofralık' (27.30 and 20.98 mm, respectively). The lowest fruit length was determined in 'Kilis yağlık' (17.30 mm) and the lowest fruit width was determined in 'Silifke yağlık' (14.86 mm) and 'Kilis yağlık' (15.08 mm) (Tables 3 and 4).

Fruit shape varied between cultivars and could be grouped into three form types. 'Manzanilla de Sevilla', 'Meski', 'Ayvalık', 'Edincik su', 'Gemlik', 'Samanlı', 'Kilis yağlık', 'Nizip yağlık', and 'Halhalı' were spheroid (L/W < 1.25), 'Memeli' and 'Sarı ulak' were elongate (L/W > 1.45) and the other cultivars were ellipsoid (1.25 ≤ L/W ≤ 1.45) (Table 4).

The largest stone was found in 'Ascolana' (1.36 g) whereas 'Kilis yağlık' and 'Nizip yağlık' had the smallest stones (0.36 and 0.41 g, respectively). The

Table 3 Alternate bearing index (ABI), fruit removal force (FRF) in green and black maturity stages, fruit removal force (FRF)/fruit weight (FW) ratio, fruit weight, and fruit length of several olive (*Olea europaea*) cultivars grown between 2001 and 2004 under Kırıkhan, Hatay, Turkey conditions.

Cultivar	Alternate bearing index (ABI)	Fruit removal force (FRF) (g)		FRF/FW	Fruit weight (g)	Fruit length (mm)
		Green maturity	Black maturity			
M. de Sevilla	0.48 f–h	574 c–e	380 ab	97.19 b–d	3.91 d	19.19 j
Hojiblanca	0.64 ab	617 a–c	346 b–e	74.73 fg	4.63 c	23.38 d–f
Ascolana	0.44 h	528 c–f	348 a–e	51.79 h	6.72 a	27.60 a
Meski	0.67 a	583 b–e	338 c–f	139.09 a	2.43 h	19.03 j
Ayvalık	0.48 f–h	509 c–f	341 b–f	99.71 bc	3.42 e–g	21.40 hı
Memecik	0.59 a–e	540 c–f	364 a–c	78.96 d–g	4.61 c	24.78 cd
Memeli	0.61 a–d	595 a–d	349 a–e	77.04 d–g	4.53 c	25.83 bc
Domat	0.45 gh	697 a	389 a	70.22 f–h	5.54 b	25.74 c
İzmir sofralık	0.49 f–h	525 c–f	322 c–f	54.48 h	5.91 b	27.30 ab
Sarı yaprak	0.45 gh	694 ab	381 ab	83.55 c–g	4.56 c	24.74 cd
Edincik su	0.48 f–h	472 ef	303 f	66.89 gh	4.53 c	21.78 gh
Uslu	0.46 gh	569 c–e	335 c–f	95.71 b–e	3.50 d–f	24.14 de
Gemlik	0.52 e–h	520 c–f	338 c–f	86.45 c–g	3.91 d	22.86 e–g
Samanlı	0.61 a–d	496 d–f	338 c–f	76.47 e–g	4.42 c	22.02 f–h
Sarı ulak	0.56 b–f	562 c–f	321 d–f	89.42 c–f	3.59 de	23.37 d–f
Silifke yağlık	0.66 a	571 c–e	339 b–f	111.51 b	3.04 g	20.15 ıj
Kilis yağlık	0.63 a–c	454 f	309 ef	150.73 a	2.05 h	17.30 k
Nizip yağlık	0.66 a	590 a–d	358 a–d	153.65 a	2.33 h	21.53 g–ı
Halhalı	0.53 d–g	547 c–f	331 c–f	89.46 c–f	3.70 de	19.69 j
Savrani	0.53 d–g	558 c–f	319 d–f	103.24 bc	3.09 fg	21.69 gh
Sarı haşebi	0.55 c–f	575 c–e	336 c–f	110.89 b	3.03 g	21.80 gh
Mean	0.5	560.7	342.1	93.39	3.9	22.6
$LSD_{0.05}$	0.08	111.70	42.48	20.20	0.45	1.52

highest fruit flesh rations were found in 'Manzanilla de Sevilla', 'Gemlik', 'Edincik su', 'Hojiblanca', and 'Halhalı' being c. 86% whereas the lowest were in 'Sarı ulak' and 'Meski' at c. 76% (Table 4).

Oil content varied significantly between cultivars ranging from 16.7% to 31.2%. The highest oil contents were in 'Kilis yağlık' (31.2%) and 'Savrani' (29.3%) whereas the lowest were in 'Hojiblanca' (18.5%), 'Edincik su' (18.3%), and 'Ascolana' (16.7%). The cumulative oil yield over 4 years also differed greatly among the cultivars. The greatest cumulative oil yields were from 'Gemlik' (6.43 kg/tree) followed by 'Memecik' (5.81 kg/tree), 'Kilis yağlık' (5.40 kg/tree), and 'Sarı ulak' (5.31 kg/tree) (Table 4).

DISCUSSION

Various horticultural characteristics of 21 olive cultivars were measured under the ecological conditions of Hatay. Both local and cultivars of foreign origin were included in the trial. Results found were comparable to those of previous studies. For example, olive trees usually start flowering during the second week of May in İzmir (Canözer 1991), during the first week of May in Antalya (Ülger et al. 2000), the first week of June in Artvin (Bolat & Güleryüz 1995), and the last week of May in Marmara (Kaynaş et al. 2002). In agreement with previous studies conducted in İzmir and Antalya, flowering started between 4 May and 10 May under Hatay conditions. 'Manzanilla de Sevilla' and 'Silifke yağlık' completed flowering earlier than the other cultivars on 14 May whereas 'Domat' and 'Memeli' completed flowering on 21 May. Similarly, Ülger et al. (2000) and Kaynaş et al. (2002) reported that 'Domat' was the latest flowering cultivar in the Antalya and Marmara regions. Flowering duration was 7–11 days in Antalya (Ülger et al. 2000) and 11–18 days in Marmara (Kaynaş et al. 2002). In our study in Hatay, flowering duration ranged from 10 to 13 days which was similar to Antalya and shorter than in Marmara.

Maturity status at harvest is a critical determinant of quality for both table and oil cultivars. Green table cultivars should be harvested at green maturity whereas black table cultivars should be harvested

Table 4 Fruit width, fruit shape index, stone weight, fruit flesh ratio, oil content (based on % fresh fruit weight), and cumulative oil yield of several olive (*Olea europaea*) cultivars grown between 2001 and 2004 under Kırıkhan, Hatay, Turkey conditions.

Cultivar	Fruit width (mm)	Fruit shape index (L/W)	Stone weight (g)	Fruit flesh ratio (%)	Oil content	Cumulative oil yield/tree (kg)
M. de Sevilla	16.19 h–k	1.19 gh	0.53 f–h	86.4 a	20.9 fg	5.22 b–e
Hojiblanca	18.70 de	1.25 ef	0.64 d–f	86.1 ab	18.5 hı	4.28 ef
Ascolana	21.31 a	1.30 de	1.36 a	79.8 d	16.7 ı	2.90 g
Meski	16.09 ı–k	1.18 gh	0.58 fg	76.1 e	28.3 b	4.62 c–f
Ayvalık	17.23 f–h	1.24 e–g	0.52 gh	84.9 a–c	25.0 c	4.55 c–f
Memecik	18.63 de	1.33 cd	0.74 d	83.9 a–c	25.1 c	5.81 ab
Memeli	17.81 ef	1.45 b	0.72 de	84.1 a–c	21.7 d–g	4.75 c–f
Domat	19.18 cd	1.34 cd	0.89 b	83.9 a–c	21.2 fg	4.58 c–f
İzmir sofralık	20.98 ab	1.30 de	0.91 b	84.5 a–c	19.9 gh	3.81 fg
Sarı yaprak	17.94 ef	1.38 c	0.76 cd	83.4 a–c	21.5 e–g	3.86 fg
Edincik su	18.05 ef	1.21 f–h	0.62 e–g	86.3 ab	18.3 hı	3.04 g
Uslu	18.33 d–f	1.32 cd	0.54 fg	84.6 a–c	22.3 d–f	3.89 fg
Gemlik	18.43 de	1.24 e–g	0.57 fg	86.4 a	24.0 cd	6.43 a
Samanlı	20.08 bc	1.10 ı	0.76 cd	82.9 b–d	21.1 fg	3.89 fg
Sarı ulak	15.23 j–l	1.53 a	0.87 bc	75.8 e	23.8 c–e	5.31 b–d
Silifke yağlık	14.86 l	1.36 cd	0.61 e–g	79.7 d	27.7 b	4.31 d–f
Kilis yağlık	15.08 kl	1.15 hı	0.36 ı	82.4 cd	31.2 a	5.40 bc
Nizip yağlık	17.64 e–g	1.22 fg	0.41 hı	82.3 cd	28.0 b	5.12 b–e
Halhalı	16.30 h–j	1.21 f–h	0.52 gh	86.0 ab	22.0 d–g	4.07 f
Savrani	16.66 g–ı	1.30 de	0.51 gh	83.5 a–c	29.3 ab	5.15 b–e
Sarı haşebi	16.17 h–k	1.34 cd	0.51 gh	83.1 a–c	24.2 cd	3.85 fg
Mean	17.6	1.2	0.6	83.1	23.3	4.52
$LSD_{0.05}$	1.12	0.06	0.12	3.42	2.36	1.02

at black maturity (Tetik 2005). Kaynaş et al. (2002) reported that green maturity started at the end of September or the beginning of October in the Marmara region and the latest green maturity cultivars were 'Domat' and 'Manzanilla de Sevilla'. Under Hatay conditions, green maturity occurs earlier than in the Marmara region. In agreement with a previous study, 'Domat' and 'Manzanilla de Sevilla' cultivars start and complete the green maturity period latest. The green maturity period ranged from 13 to 22 days depending on cultivar. Kaynaş et al. (2002) found that green maturity ranged from c. 12 to 30 days depending on cultivar. Kaynaş et al. (2002) reported that black maturity begins in the last week of November. Black maturity occurs earlier under Hatay conditions, than in the Marmara region. Similar to our results, Canözer (1991) in İzmir and Ülger et al. (2000) in Antalya, reported that 'Gemlik' and 'Uslu' reached black maturity earlier and 'Domat' and 'Halhalı' reached black maturity later.

Similar to our findings, Canözer (1991) reported that 'Uslu', 'Domat', and 'Memecik' developed vigorously under İzmir conditions. Kaynaş et al. (2000) determined that Gemlik had an intermediate canopy volume whereas 'Ascolana' and 'Hojiblanca' had large canopy volumes in the Marmara region. Trunk cross-section and canopy volume vary significantly between different olive cultivars in Spain (Del Rio & Caballero 1994; Tous et al. 2002).

Although average productivity results are not directly comparable to those of previous studies because of the juvenility of the trees in our trial, it is possible to compare the productivity rankings of the cultivars. Kaynaş et al. (2000) determined that 'Hojiblanca', 'Gemlik', and 'Manzanilla de Sevilla' cultivars produced the highest yields in the Marmara region. In Antalya, the highest yield was recorded in 'Manzanilla de Sevilla' and 'Uslu' (Ülger et al. 2000). Leitao (1990) in Portugal and Del Rio & Caballero (1994) and Tous et al. (2002) in Spain, reported that there were significant differences between cultivars in productivity and that ecological factors also had significant impacts on yield. ABI, an important horticultural characteristic related to productivity, varied among cultivars. Barut & Eriş (2000) and Kaynaş et al. (2000) have also discovered genotypic differences in ABI.

In olive production, a major part of the overall production cost is the cost of harvesting. Harvest machines are used especially in countries in which labour is expensive. Tree canopy shape, fruit weight, maturity stage and fruit removal force all have significant affects on the efficacy of a harvest machine (Antognozzi et al. 1990; Proietti et al. 2002). Our findings give us the opportunity to compare some of these characteristics for 21 cultivars, and we identified notable differences among those tested. FRF varies significantly among the cultivars (Antognozzi et al. 1990; Preziosi & Tini 1990; Tous et al. 2002). As fruit maturity increases, FRF decreases (Proietti et al. 2002; Sessiz & Özcan 2006). This was true in our study too. We found that the ratio of fruit removal force/fruit weight (FRF/FW) was high in cultivars with small fruits such as 'Kilis yağlık', 'Nizip yağlık', and 'Meski' and low in cultivars with large fruits such as 'Ascolana', 'İzmir sofralık', and 'Edincik su'. Our findings are in agreement with those of Tous et al. (2002). However, Tous et al. (2002) found FRF/FW values between 105.9 and 348.0 when harvested at maturity indexes of 3 and 4, whereas our ratios ranged from 51.79 to 153.65 at black maturity 5—this difference is not surprising.

All cultivars tested produced marketable fruits based on the characteristics for either table or oil production. The results show that some table olive cultivars produce fruits of commercial quality (big fruit and high fruit flesh ratio) in the Hatay region which till now has been known mainly for its oil production.

The cultivars used in this study reached both green and black maturity stages earlier in Kırıkhan than in İzmir or Marmara where olives are grown intensively. Early maturity allows an extension of the working period for processing companies for green and black table olives. The harvest period can be extended by planting new olive cultivars having either earlier or later maturity times. This reduces the need for a large harvest labour force over short time periods and it also reduces quality losses owing to processing hold ups. It is suggested that 'Gemlik', 'İzmir sofralık', 'Sarı yaprak', and 'Savrani' with their small canopy volumes are suitable for intensive planting systems with appropriate pruning. Because 'Ascolana', 'İzmir sofralık', and 'Edincik su' have the lowest fruit removal force/fruit weight ratio, it is possible that the efficacy of mechanised harvesting will be higher for these cultivars. 'Savrani', 'Sarı haşebi', and 'Halhalı' are intensively grown in this area and are mainly processed for oil, but a small proportion of production is used for table olives. It seems that 'Manzanilla de Sevilla' and 'Gemlik' with high cumulative yields and high fruit flesh ratios would be suitable for table olive production

in this area. In addition to local olive cultivars, 'Memecik', 'Kilis yağlık', and 'Sarı ulak' with high yields and high oil contents would seem suitable for oil production. The oil qualities of these cultivars were acceptable (Oktar 1989). In this way, the olive cultivars grown in Hatay province should be able to be diversified and new employment possibilities thereby created.

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