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Fruit Growth, Quality and Anatomy Characters of Four Olea europaea Cultivars Grown in Basrah Region

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Abstract
This study was conducted on olive trees, cvs, Chemlali, Dekel, Khastaui and Khuderi grown in Basrah region during the growing seasons of 2010 – 2012. The aim of this study was to investigate some of the phenological characters, preharvest physical and oil changes, quality and anatomy of mature fruits, and to determine the time for fruit harvest of these cultivars in Basrah region. Results of the phenological characters showed the onset of bud burst occurred in March, anthesis and fruit set during April and ripening in late August and early September. The physical characters of the developing fruits in the four olive cultivars were progressively increased with time up to the ripe stage. The increasing percentage of the these characters, except that of seed fresh weight, revealed a double sigmoid growth pattern with a rapid growth during stage I (30-39 days duration), slow growth during stage II (11 days duration), and a second rapid growth during stage III up to ripening time (84-100 days duration). Fruit oil content increased steadily as the fruits advanced toward the ripening stage . The percentage of oil in the fruits showed a sharp rise during June in all cultivars. The main fatty acids in the oil were palmitic, palmitoleic, stearic, oleic and linoleic acids. Oleic acid was the major fatty acid in the fruit oil of the studied cultivars. Evalution of mature fruits revealed that Dekel, Khastaui and Khuderi cultivars recorded significant increases in inflorescence length, fruit and seed fresh weight, volume, length, total acidity, total sugars, reducing and non – reducing sugars, and cell width. Chemlali, Dekel and Khuderi cultivars had significant increases in the number of flowers of inflorescence, fruit moisture content, nitrogen, crude protein and ash concentration. Chemlali, Khastaui and Khuderi cultivars recorded significant increases in dry matter percentage, lower epidermis layer thickness, cell length and vascular bundle thickness. Chemlali and Dekel cultivars recorded significant increases in potassium concentration and number of cells in mm^{-2} of inner mesocarp. Dekel and Khuderi cultivars had significant increases in inflorescence width, fruit yield and total soluble solids. Chemlali, Dekel and Khastaui cultivars had significant increases in fruit diameter and cuticle layer thickness. Chemlali and Khuderi cultivars recorded significant increase in number of vascular bundles, whereas Dekel and Khastaui cultivars gave significant increase in epidermis layer thickness. Khastaui and Khuderi cultivars recorded significant increase in sclernchyma layer thickness. Chemlali, Khastaui and Khuderi cultivars had significant increases in phosphorus concentration, oil percentage and pollen grain viability respectively. The most appropriate time for fruit harvest in these olive cultivars is either in August for food uses or in September and early October for oil extraction under the environmental conditions of Basrah region .
Keywords: *Olea europaea* L., phenology, fruit growth, quality, anatomy, cultivars.

INTRODUCTION

The olive species *Olea europaea* L., belongs to the family Oleaceae and originated in the Eastern Mediterranean basin (Lavee, 1985; Breton et al, 2006). Olive trees grow in some areas of Central and Kurdistan of Iraq and cultivated in both regions for over 3000 years as one of the major fruit crops due to its nutritional, economic and environmental values (Mahdi, 2004; AL-Juboory, 2011). The numbers of indigenous and foreign olive cultivars grown in the agricultural lands of Iraq are approximately 44 cultivars (Agha and Daoud, 1991; Mahdi and AL-Koaz, 2007). The estimate numbers of 662 652 trees of olive are grown in Iraq covering an area of 5000 hectares with annual production of 15113 tons (COSIT,2010) . Basrah Governorate is situated in the far South of Iraq at the Northwestern corner of the Arabian Gulf (46° 60́ to 48° 60́ E and 29° 13́ to 31° 29́ N), occupying a total area of 19 070km^2 (Hadeel et al,2010). The climate of Basrah is a desert – type environment, characterized by a long – hot and dry summer, and a relatively mild winter, with scanty rainfall, favoring olive cultivars that require low winter chilling for blooming and fruiting. The annual report of Agriculture Office of Basrah recorded approximate numbers of 2390 olive trees spreading in many orchards of Basrah region (MA, 2013). There is no experimental data available on the physiology of olive species in Basrah except that of Mohammed (1999) on the effect of pruning levels on the fruit physico-chemical compositions of olive trees, cv. Dekel. The olive fruit exhibited the periodic growth behavior of stone fruits, showing a double sigmoid growth pattern with two stages of rapid growth interrupted by a stage of slow growth (Hartmann and Opitiz, 1977; Tombesi, 1994; Desouky *et al*., 2010). Olive fruit is a good source of income because it contains carbohydrates, proteins, vitamins (A, B, C, D, E and K) and minerals (K, Ca, Mg, P and Fe) (Brbandi, 2007). Olive is rich in monounsaturated fatty acids (Oleic and palmitoleic), and polyunsaturated fatty acids (linoleic and linolenic), and has many anti-oxidative compounds, such as, phenolic acids (Stark and Madar, 2002).

Dauod (1975) found that fruits of indigenous olive cultivars of Khastaui and Dekel had an average oil

percentage of 8.9% and 17.1% respectively. Abdullah (1991) observed varietal differences among five olive cultivars grown in Central Iraq with Labeeb cultivar having the highest values of fruit fresh weight and volume, whereas Chemlali cultivar recorded the highest oil percentage and total yield of tree in comparison to the other cultivars. El-Abadi (2007) revealed that olive fruits of Ashrsai cultivar recorded an average of 67.64%, 0.98%, 2.53%, 6.94% and 0.072% for moisture, ash, protein, oil and acidity respectively. Samia Dabbou *et al*., (2011) showed that fatty acids content of Tunisian olive oils was oleic acid ranging from 66.21 – 72.81%, linoleic acid from 10.92 – 14.92%, Palmitic acid from 9.45 – 11.25 %, and stearic acid from 2.6 - 2.95%. Benkhayal et al., (2014) found that the fatty acids content of Libyan olive oils was oleic acid within the range of 53.7 – 76.2%, linoleic acid from 7.6 – 25.2%, palmitic acid from 7.7- 20.1% and stearic acid from 0.4 - 4.3%. Therefore, the present investigations were undertaken to study some of the phenological characters and the preharvest physical and oil changes associated with growth and development of fruits. A focus was also made on the anatomy and quality of mature fruits including fatty acids content and to determine a most appropriate time for harvest of four olive cultivars under the environment prevailing Basrah region.

MATERIALS AND METHODS

The present investigations were carried out on twelve years old olive trees of Chemlali, Dekel, Khastaui and Khuderi cultivars during the growing seasons of 2010, 2011 and 2012, starting from 1st March to 5th September of each year. Each cultivar was represented by four trees, grown in a clay loam soil and spaced 5X5 m apart in a private orchard at Abi El-Khassib District, Basrah Governorate. Selected olive trees were similar in vigour, free from any visible pathogenic symptoms, and subjected to the common cultural practices. The trees had adequate water throughout the experimental seasons. The orchard soil was analyzed and some of its physico - chemical characters were listed in Table (1).

Table 1 : Soil and irrigation water analysis of the olive orchard.

Sample No.	Depth (cm)	EC (ds m^{-1})	PH	Water table (cm)	Particle size analysis (gm kg^{-1})			Texture class
					Clay	Silt	Sand	
Soil 1	0-30	2.6	8.21		362.5	343.4	294.1	Clay loam
Soil 2	30-50	3.2	7.99	120	325.0	325.1	354.1	Clay loam
Soil 3	50-100	3.4	8.05		404.2	283.3	312.5	Clay loam
Irrigation water		4.2	7.31					

Records on dates of olive phenology including bud burst, flowering, fruit set and ripening were made for the studied cultivers. Total numbers of flowers per inflorescence were counted on random samples of 10 inflorescences per tree at anthesis. Determination of pollen viability was made by aceto – carmine staining technique according to the method described by Dhaliwal et al, (1982). The daily maximum and minimum temperatures were supplied by " The Meteorological Office " , Basrah International Airport , to calculate the effective heat units (heat summations) required for fruit ripening in each cultivar .

The formula used in this calculation is given below

Heat summations (°C) =

Sum of monthly mean temperatures from bud burst to ripeness – (Corresponding number of days × 10).

The base temperature for the resumption of active growth in olive species is 10 °C [50 °F] (Lavee , 1985).

Measurements were also undertaken of randomly chosen 10 inflorescences per tree to obtain their maximum length and width at the time of full- sized inflorescences on the 15th June of 2010 – 2012. Determination of fruit growth was achieved by collecting 15 fruits at each sampling time randomly from several inflorescences on the labelled olive tree at intervals from 21st April to 5th September 2010-2012. Collected fruits were used for calculating the average fruit length, diameter and volume . Fresh and dry weights of fruit and seed were determined and from this the fruit moisture content and dry matter percentage were calculated. Total soluble solids, total acidy and total, reducing and non – reducing sugars were estimated by standard methods (AOAC, 2000).

The oven dried fruit materials were vigorously ground, digested according Cresser and Parsons (1979) and analyzed for nitrogen, phosphorus and potassium determinations as described by Page et al, (1982).

The values of nitrogen were multiplied by 6.25 to obtain crude protein content. Fruit ash content was determined by a Muffle Furnace at 525 °C for 16 hours as outlined by AOAC (2000).

Fruit oil content was determined by Saxhelt Fat Extractor using petroleum ether of 40-60 °C boiling point as outlined by Guenther (1972), and from this oil percentage of fruit, oil yield of tree and oil productivity of hectare were calculated.

Fatty acid methyl esters of olive oil cultivars were prepared by the method of Kang and Wang (2005)

using BF3/methanol reagent. Oil sample was mixed with 1ml hexane in tightly sealed 10 ml pyrex tube. 1ml of BF3 / MeOH reagent was added and the mixture was heated at 90-100 °C in a water bath for 1 hour, and then cooled to room temperature. Methyl esters in the hexane phase was extracted after addition of 1ml H2O. Samples were allowed stand for 20-30 min, and then the distinct upper hexane layer was removed carefully and concentrated under nitrogen. Fatty acid methyl esters were analyzed by Gas chromatography coupled to Mass Spectrometry, type QP 2010 Ultra, Shimadzu Co, Japan, equipped with DB-1ms: 30m x 0.25 mm x 0.25 µm film thickness capillary column. Helium was the carrier gas, and injector temperature was set to 280 °C. Initial column temperature was programmed at 50 °C for 3 min, increased to 280 °C at 5 °C min^{-1}, and then was set at 280 °C for 5 min. The GC-MS operating conditions were as follows:

Gas Chromatography	Mass Spectrometer
Column Oven temp: 50.0 °C	**IonSource Temp: 200.00 °C**
Injection temp: 280.00 °C	**Interface Temp: 280.00 °C**
Injection Mode: Split	**Solvent Cut Time: 3.00 min**
Flow Control Mode: Linear Velocity	**Start Time: 3:00 min**
Pressure: 100.1 KPa	**End Time: 31.00min**
Total Flow: 55.5 mL/min	**ACQ Mode: Scan**
Column Flow: 1.69 mL/min	**Event Time: 0.50 sec**
Linear Velocity: 47.2cm/sec	**Scan Speed: 1666**
Purge Flow: 3.0 mL/min	**Start m/z: 50.00**
Split Ratio: 30.0	**End m/z: 800.00**

1 µL of the FAMEs aliquots was injected into the chromatographic column and peaks were recorded for their respective retention times and areas by the data processor of the GC. Identification of each individual FAME was achieved by comparison with those of NIST 08 library spectra.

To obtain anatomical sections, fresh materials of mature fruits were fixed at least 48 hours in formalin acetic acid alcohol solution (FAA), dehydrated in increasing concentrations of ethanol and embedded in liquid paraffin medium. Paraffin sections were made by a Rotary Microtome, stained with safranin and fast-green solutions and then mounted in Canada balsam (Johansen, 1940). The sections were examined with Olympus CH4 light microscope and photographed with digital camera type DCE-2 for determinations of some anatomical characters of fruits.

Olive trees were harvested by hand as the fruit colour changes from green to red to black during late August and September of each year and weighed to determine total yield of the tree.

STATISTICAL ANALYSIS

A completely randomized block design was used in this study. Each of the four cultivars was considered as a treatment and each of the four trees as an experimental unit. Collected measurements of inflorescences, flowers and mature fruits were combined to obtain the averages of the three constative years which were statistically analyzed using Gen State software (2013). One way analysis of variance was conducted for different parameters and the least significant difference test was used to differentiate means at 0.05.

RESULTS AND DISCUSSION

PHENOLOGY OF OLIVE CULTIVARS

The phenology of olive was achieved during the growing seasons of 2010-2012 through visual observation of the labelled trees for Chemlali, Dekel. Khastaui and Khuderi cultivars (Table 2). The commencement of bud burst tookplace on the 1st March in all the studied cultivars and inflorescences were clearly visible two weeks later.

The occurrence of full bloom (anthesis 50% of flowers opening) differed among cultivars starting from early April in Dekel and Khastaui cultivars to mid- April in the remaining cultivars. Fruit setting was earlier on the 18th April in Dekel and Khastaui , followed by Khuderi and Chemlali on the 21st and 25th April respectively .

The onset of ripening, which was indicated by the softening and colouring of fruits, occurred in late August for Dekel , Khastaui, and Khuderi and early September for Chemlali cultivar . These findings were mainly related to the blooming time of cultivars, associated with the environmental condition in which the olives were grown.

Table 2: Observations on bud burst, anthesis, fruit set and ripening of four olive cultivars grown in Basrah region. Data represents the mean of three consecutive years (2010 – 2011 – 2012).

Cultivar	Bud burst	Anthesis	Fruit set	Ripeness
Chemlali	**1st March**	**17th April**	**25th April**	**5th Sept.**
Dekel	**1st March**	**8th April**	**18th April**	**24th Aug.**
Khastaui	**1st March**	**11th April**	**18th April**	**30th Aug.**
Khuderi	**1st March**	**15th April**	**21st April**	**20th Aug.**

The inflorescence development subsequent to bud burst is mainly correlated with crop load, fertilization,

water availability, heat summations and assimilation of carbon via leaf photosynthesis (Lavee, 1985; Proietti, 2003; Brabandi, 2007).

Consideration was only given to the requirements of heat summations for each cultivar under the environmental conditions of Basrah (Table 3). Heat summations needed for Khuderi, Dekel, Khastaui and Chemlali, over a period of (173,177, 183 and 189) days, were 3823.21°C, 3935.88°C, 4010.03° C and 4257.99 °C respectively. It can be concluded, therefore, that all these cultivars are late ripe ones. These findings agreed with Jamal and Alsousow (2009) as they reported that early ripe olive cultivars require heat summations of 3500 – 3600 °C, whereas late ripe ones require 3600 to 4200 ° C heat summations.

Table 3: Heat summation (° C) and number of days from bud burst to ripening stage for Chemlali, Dekel, Khastaui and Khuderi olive cultivars grown in Basrah region during the seasons of 2010-2012.

Cultivar	Heat summation (° C)	Corresponding no. days
Chemlali	**4257.99**	**189**
Dekel	**3935.88**	**177**
Khastaui	**4100.03**	**183**
Khuderi	**3823.21**	**173**

Data presented in Table (4) revealed significant differences between olive cultivars in regard to inflorescences dimension. The highest averages of inflorescence length and width were recorded for Khuderi and Dekel respectively, whereas the lowest averages were obtained from Chemlali cultivar. Significant differences in the number of flowers per inflorescence were found between olive cultivars. The highest average was recorded for Khuderi , followed by Chemlali and Dekel respectively , whereas the lowest average was given by Khastaui in this respect . Results of pollen grain viability showed no significant differences between cultivars, with the exception of Khuderi cultivar being significantly higher than Chemlali cultivar. These finding did account for good fertilization and fruit setting in these cultivars indicating normal development of floral organs under local environmental conditions. Data of yield per tree varied from 10kg in Khastaui to 16 kg in Khuderi cultivars (Table 4). Dekel and Khuderi recorded significant increases in yield of tree as compared to that of Khastaui. No significant difference was observed between yield of Chemlali and that of Khastaui. In comparison, Abdullah (1991) found that yield of five olive cultivars grown in Central Iraq ranged from 28.15 kg tree^{-1} in Labeeb to 54.33kg tree^{-1} in Chemlali. The report of FAOSTAT (2014) on total yield of olive in Iraq revealed an estimation of 4.91 ton ha^{-1}, whereas the studied cultivars produced an average yield of (4-6.4) ton ha^{-1} under local environments.

Table 4: Inflorescence, flower and fruit characters of four olive cultivars.

*** Each value represents the average of four replicates for the years of measurements.**

Cultivar	Inflorescence			Flower	Fruit
	Max.length (cm)	Max. width (cm)	No. flowers inflorescence^{-1}	Pollen grain viability (%)	Yield (kg tree^{-1})
Chemlali	**4.47 ***	**1.63**	**19.07**	**80.00**	**13**
Dekel	**5.05**	**2.20**	**16.52**	**92.00**	**15**
Khastaui	**4.70**	**1.72**	**9.61**	**88.88**	**10**
Khuderi	**5.64**	**1.97**	**26.67**	**92.68**	**16**
LSD P≤0.05	**0.20**	**0.19**	**0.09**	**12.00**	**3.5**

GROWTH PATTERN OF THE FRUITS

The fruits of Khuderi and Dekel cultivars attained the ripe stage within (127 and 138) days from anthesis , whereas Chemlali and Khastaui took 141 days between anthesis and ripening stage (Tables 5 , 6 , 7 and 8) .The averages of fruit fresh weight , volume, length and diameter showed a double sigmoid growth pattern with three phases of growth being observed in all cultivars. The initial phase of rapid growth, stage 1, had a length of (30, 32,36 and 39) days of anthesis for Chemlali, Khuderi, Khastaui and Dekel respectively. The lag phase of slow growth, stage II, had a length of 11 days in all cultivars. The second phase of resumed growth and ripening, stage III, was markedly increased in all the studied parameters, and then the increases were gradual and remained more or less constant prior to the ripening stage in all cultivars. The duration of this stage up to ripening time was (84,88,94 and 100) days for Khuderi , Dekel , Chastaui and Chemlali respectively .These findings were in line with those reported by Hartmann (1948) on Manzanillo cultivar and Desouky et al,(2010) on Arbequina , Bouteillan and Koroneiki cultivars . The increasing percentage of fruit fresh weight, volume, length and diameter at stage I was a result of intense cell division and cell enlargement of the exocarp, mesocarp and endocarp and of seed growth (Tables 5,6,7, and 8). At stage II, the increasing percentage was low in all cultivars and this could be attributed to the slow growth of the pericarp. At stage III, the increasing percentage was initially due to the resumption of cell enlargement and then to the gain accumulated substances for fruit ripening (Tombesi 1994;

Proietti, 2003; Desouky et al , 2010) . The average seed fresh weight increased markedly up to (16,23,30 and 36) days after anthesis in Khuderi , Dekel , Chemlali and Khastaui respectively.Average seed fresh weight continued to increase throughout the developmental stages and remained fairly constant up to the ripening stage . Similar findings were found by Proietti (2003).

Table 5: Growth pattern of Chemlali olive fruit represented by some physical characters and their percentage of increases during the growing seasons of (2010-2012).

***Each value represents combined averages of four replicates for the years of measurements.**

Days after anthesis	Av wt. of fruit (g)	Increase (%)	Av wt. of seed(g)	Increase (%)	Av vol. of fruit (ml)	Increase (%)	Av length of fruit (cm)	Increase (%)	Av diam.of fruit (cm)	Increase (%)
4	0.126*	0.0	0.03	0.0	0.150	0.0	0.610	0.0	0.310	0.0
14	0.330	161.90	0.08	166.67	0.330	120.0	1.080	77.05	0.534	72.26
30	0.554	67.88	0.23	187.50	0.500	51.52	1.388	28.52	0.700	31.09
41	1.528	175.81	0.44	91.30	1.458	191.60	2.022	45.68	1.308	86.86
55	2.341	53.21	0.52	18.18	2.232	53.09	2.118	4.75	1.480	13.15
69	2.862	22.26	0.63	21.15	2.78	24.55	2.136	0.85	1.629	10.07
83	3.260	13.91	0.68	7.94	3.14	12.95	2.150	0.66	1.79	9.88
97	3.700	13.50	0.71	4.41	3.50	11.46	2.163	0.60	1.86	3.91
114	3.780	2.16	0.74	4.23	3.74	6.86	2.174	0.51	1.92	3.23
129	3.81	0.79	0.77	4.05	3.80	1.60	2.180	0.28	1.96	2.08
141	3.83	0.52	0.77	0.0	3.80	0.0	2.180	0.0	1.96	0.0

Table 6: Growth pattern of Dekel olive fruit represented by some physical characters and their percentage of increases during the growing seasons of (2010-2012).

***Each value represents combined averages of four replicates for the years of measurements.**

Days after anthesis	Av wt. of fruit (g)	Increase (%)	Av wt. of seed(g)	Increase (%)	Av vol. of fruit (ml)	Increase (%)	Av lenght of fruit (cm)	Increase (%)	Av diam. of fruit (cm)	Increase (%)
13	0.220*	0.0	0.14	0.0	0.25	0.0	0.63	0.0	0.60	0.0
23	0.530	140.91	0.30	114.29	0.50	100.0	1.08	71.43	1.00	66.67
39	0.780	47.17	0.60	100.0	0.70	40.0	1.40	29.63	1.28	28.00
50	2.032	160.51	1.08	80.0	1.90	171.43	2.49	77.86	2.13	66.41
64	3.260	60.43	1.20	11.11	3.16	66.32	3.08	23.69	2.25	5.63
78	4.550	39.57	1.32	10.0	4.52	43.04	3.20	3.90	2.36	4.89
92	5.631	23.76	1.44	9.09	5.60	23.89	3.30	3.13	2.45	3.81
106	6.788	20.55	1.52	5.56	6.70	19.64	3.37	2.12	2.53	3.27
123	7.158	5.45	1.60	5.26	7.20	7.46	3.42	1.48	2.60	2.77
138	7.49	4.64	1.68	5.0	7.47	3.75	3.45	0.88	2.65	1.92

Table 7: Growth pattern of Khastaui olive fruit represented by some physical characters and their percentage of increases during the growing seasons of (2010-2012).

***Each value represents combined averages of four replicates for the years of measurements.**

Days after anthesis	Av wt. of fruit (g)	Increase (%)	Av wt. of seed(g)	Increase (%)	Av vol. of fruit (ml)	Increase (%)	Av length of fruit (cm)	Increase (%)	Av diam. of fruit (cm)	Increase (%)
10	0.15*	0.0	0.02	0.0	0.18	0.0	0.52	0.0	0.28	0.0
20	0.39	105.26	0.05	150.0	0.38	111.11	1.00	92.31	0.47	67.86
36	0.65	66.67	0.14	180.0	0.60	57.89	1.43	43.00	0.71	51.06
47	1.73	166.15	0.30	114.29	1.72	186.67	1.76	23.08	0.98	38.03
61	3.14	81.50	0.51	70.0	3.00	74.42	2.00	13.64	1.20	22.45
75	3.72	18.47	0.60	17.65	3.80	26.67	2.10	5.00	1.36	13.33
89	4.26	14.52	0.70	16.67	4.18	10.00	2.20	4.76	1.42	4.41
103	4.70	10.33	0.80	14.29	4.60	10.05	2.30	4.55	1.48	4.23
120	5.17	10.00	0.89	11.25	5.00	8.70	2.39	3.91	1.52	2.70
135	5.62	8.70	0.94	5.62	5.40	8.00	2.43	1.67	1.55	1.97
141	5.71	1.60	0.95	1.06	5.65	4.63	2.45	0.82	1.56	0.65

Table 8 : Growth pattern of Khuderi olive fruit represented by some physical characters and their percentage of increases during the growing seasons of (2010-2012).

***Each value represents combined averages of four replicates for the years of measurements.**

Days after anthesis	Av wt. of fruit (g)	Increase (%)	Av wt. of seed(g)	Increase (%)	Av vol. of fruit (ml)	Increase (%)	Av length of fruit (cm)	Increase (%)	Av diam. of fruit (cm)	Increase (%)
6	0.278*	0.0	0.30	0.0	0.25	0.0	1.285	0.0	0.65	0.0
16	0.744	167.63	0.65	116.67	0.50	100.0	1.796	39.77	0.90	38.46
32	0.980	31.72	1.05	61.54	0.80	60.0	1.802	33.41	1.16	28.89
43	2.700	175.51	1.20	14.29	1.90	137.50	2.470	37.07	1.58	36.21
57	4.867	80.26	1.28	6.67	3.571	87.95	2.781	12.59	1.804	14.18
71	6.272	28.87	1.36	6.25	5.833	63.34	2.98	7.16	2.052	13.75
85	7.81	24.52	1.43	5.15	7.75	32.86	3.090	3.69	2.23	8.67
99	8.90	13.96	1.50	4.90	8.66	11.74	3.20	3.56	2.35	5.38
116	9.90	11.24	1.57	4.67	9.20	6.24	3.25	1.56	2.40	2.13
127	9.95	0.51	1.59	1.27	9.73	5.76	3.29	1.23	2.42	0.83

Data of mature olive fruits were presented in Table (9). Average fruit fresh weight and volume ranged from 3.83 g and 0.80 ml in Chemlali to 9.95g and 9.73ml in Khastaui cultivars respectively. Dekel, Khastaui and Khuderi cultivars recorded significant increases in both parameters as compared to Chemlali cultivar. Significant differences were also found among the three cultivars regarding fruit fresh weight and volume. Average seed fresh weight was lowest (0.77g) in Chemlali and highest (1.68g) in Dekel cultivars. Dekel, Khastaui and Khuderi cultivars were significantly higher than Chemlali cultivar in this respect. All the three cultivars recorded significant differences between them regarding seed fresh weight. Average fruit length and diameter varied from 2.18cm in Chemlali and 1.56cm in Khuderi to 3.45cm and 2.65 cm in Dekel cultivars respectively. Dekel, Khastaui and Khuderi cultivars were significantly higher than Chemlali cultivar in fruit length. Significant differences were also found among the three cultivars in this respect. Chemlali, Dekel and Khastaui cultivars recorded significant increase in fruit diameter as compared to Khuderi cultivar. There were significant differences between the three cultivars concerning fruit diameter. These findings were in line with those obtained by Desouky et al., (2010) and Ebiad and Abdu-Qaoud (2014).

Table 9: Fruit and seed fresh weight, volume, length and diameter of mature fruits of four olive cultivars.

***Each value represents combined averages of four replicates for the years of measurements.**

Cultivar	Av wt. of fruit (g)	Av wt. of seed (g)	Av vol. of fruit (ml)	Av length of fruit (cm)	Av diam. of fruit (cm)
Chemlali	3.83*	0.77	3.8	2.18	1.96
Dekel	7.49	1.68	7.47	3.45	2.65
Khastaui	9.95	1.59	9.73	3.29	2.42
Khuderi	5.71	0.95	5.65	2.45	1.56
LSD at P ≤ 0.05	0.086	0.082	0.127	0.09	0.091

CHEMICAL CHARACTERS

There were significant variations among olive cultivars in relation to chemical characters of ripe fruits (Table 10). The average moisture content ranged from 59.08% in Khastaui to 63.93% in Dekel cultivars. Chemlali, Dekel and Khuderi cultivars were significantly higher than Khastaui cultivar in this respect. The difference between the three cultivars was also significant regarding moisture content. Average percent dry matter varied from 36.07% in Dekel to 40.92% in Khastaui cultivars. Chemlali, Khastaui and Khuderi cultivars had significantly more dry matter in comparison to Dekel cultivar. Significant differences were also found between the three cultivars in respect of dry matter content. The differences in fruit moisture and dry matter content of these olive cultivars may be related to their genetic variability, accumulation of total soluble solids and transpiration rate associated with the onset of fruit ripening.

Average TSS was lowest (11.90%) in Chemlali and highest (19.00%) in Dekel cultivars. Dekel recorded significant increase in TSS as compared to the remaining three cultivars. Significant difference was also found between Khuderi and Chemlali cultivars in respect of TSS. The accumulation of acids and sugars, depending on the efficiency of photosynthetic process and the sink strength of the fruits of each cultivar, may account for such differences in TSS concentration of the fruits.

Average total acidity ranged between 0.604% in Chemlali to 1.190 % in Dekel cultivars. Dekel , Khastaui and Khuderi cultivars were significantly higher than Chemlali cultivar in this respect . There were also significant differences between the three cultivars regarding total acidity of the fruits. The differences in fruit total acidity of these cultivars may be attributed to their activities of accumulating organic acids on the account

of translocation from leaves or the synthesis within the fruits.

The range of total and reducing sugars varied from 10.202% and 8.393 % in Chemlali to 11.178% and 9.163% in Dekel cultivars respectively. Dekel, Khastaui and Khuderi cultivars recorded significant increases in total and reducing sugars as compared to Chemlali cultivar. Significant differences were also obtained between there cultivars in this respect. Average non-reducing sugars was lowest (1.809%) in Chemlali and highest (2.197%) in Khuderi cultivars. All the cultivars were significantly higher than Chemlali cultivar regarding non – reducing sugars . There were also significant differences between the three cultivars in this respect. The observed differences in sugars concentration of olive cultivars fruits may be due to the accumulation of carbohydrates, produced in the leaves, and to the activity of starch enzymes to convert starch granules into sugars.

Table 10: Moisture, dry matter ,total soluble solids (TSS), total acidity and sugars of mature fruits of four olive cultivars.

***Each value represents combined averages of four replicates for the years of measurements.**

Cultivar	Moisture (%)	Dry matter (%)	TSS (%)	Total acidity (%)	Total sugars (%)	Reducing sugars(%)	Non-reducing sugars (%)
Chemlali	61.05*	38.95	11.90	0.604	10.202	8.393	1.809
Dekel	63.93	36.07	19.00	1.190	11.178	9.163	2.015
Khastaui	59.08	40.92	12.50	0.777	10.385	8.547	1.838
Khuderi	62.53	37.47	14.50	0.880	10.975	8.778	2.197
LSD P≤ 0.05	0.10	0.10	2.01	0.047	0.001	0.009	0.008

MINERAL CONTENT

The average nitrogen and crude protein concentrations of mature olive fruit ranged from 0.37% and 2.31% in Khastaui to 1.10 % and 6.88% in Dekel cultivars respectively (Table 11). Chemlali, Dekel and Khuderi cultivars recorded significant increases in both parameters as compared to Khastaui cultivar. Significant differences were found among these cultivars concerning nitrogen and crude protein concentrations. The average phosphorus concentration varied from 0.59% in Khastaui to 0.75% in Chemlali cultivars. Significant difference was found between Chemlali and Khastaui cultivars in this respect. The average potassium concentration ranged between 0.26% in Khastaui to 0.54% in Dekel cultivars. Dekel cultivar recorded significant increase in potassium concentration in comparison to the other olive cultivars. Chemlali cultivar was also significantly higher than that of Khastaui cultivar. The average ash concentration was between 1.253% in Khastaui and 2.527% in Chemlali cultivars. Chemlali differed significantly from the other cultivars, Dekel from Khastaui and Khuderi, and Khuderi from Khastaui cultivar than Khastaui cultivar in this respect. The differences in crude protein concentration of mature fruits may be due to the consumption of proteins as enzymes in the metabolic processes associated with fruit ripening in these cultivars. On the other hand, the use of minerals in the cellular function of the fruits in conjection with the process of fruit ripening may account for such difference in these cultivars. El-Abadi (2007) reported 2.53% and 0.98% crude protein and ash concentrations in mature fruits of Ashrasi olive cultivar which were close to crude protein and ash contents found in the present study.

Table 11: Nitrogen, phosphorus, potassium, crude protein and ash concentration of mature fruits of four olive cultivars.

***Each value represents combined averages of four replicates for the years of measurements**.

Cultivar	Nitrogen (%)	Phosphorus (%)	Potassium (%)	Crude Protein (%)	Ash (%)
Chemlali	0.55*	0.75	0.39	3.44	2.527
Dekel	1.10	0.67	0.54	6.88	1.555
Khastaui	0.37	0.59	026	2.31	1.253
Khuderi	0.44	0.64	0.35	2.75	1.400
LSD P≤ 0.05	0.01	0.11	0.12	0.12	0.011

OIL CONTENT

As shown in Table (12), the fruit oil content began to accumulate gradually after fruit setting. A rapid increase in oil content was observed in June and reached its maximum when the fruit colouration occurred in late August and September, depending on cultivars. The r values for the relationship between fruit oil content and mean monthly temperature, over the period of measurements, was positive and significant indicating a normal accumulation of oil in the fruit of all cultivars under the environmental conditions of Basrah region (Table 12).

The percentage of increase in fruit oil content was low initially , followed by a sharp rise in June and then it was progressively low as the fruits advanced toward ripening stage (Table 13).Tombesi (1994) found that the mesocarp cells of olive fruit started to produce oil 45 days of anthesis and oil accumulation was very intense after 60 days of anthesis .The obtained results were in accordance with the findings of Abdullah (1991) on Chemlali and Khastaui cultivars and El-Abadi (2007) on Ashrasi cultivar .

Table 12: Changes in % oil of developing fruits of four olive cultivars and mean monthly temperature during the growing seasons of (2010-2012).

***Each value represents combined averages of four replicates for the years of measurements.**

****Each value represents combined monthly temperatures (°C) for the years of measurements.**

Cultivar / Month of measuresmeant	Chemlali		Dekel		Khastaui		Khuderi	
	% oil	Mean temp.	% Oil	Mean temp.	% Oil	Mean temp.	% Oil	Mean temp.
May	1.70*	33.04**	1.80	33.04	2.80	33.04	2.10	33.04
June	6.80	37.54	4.40	37.54	7.40	37.54	9.40	37.54
July	11.50	39.69	9.20	39.69	13.80	39.69	11.50	39.69
August	14.18	38.58	12.91	38.58	18.41	38.58	13.16	38.58
Correlation coefficient P≤ 0.05	R =0.90		R =0.79		R =0.83		r =0.96	

Table 13: The increasing percentage of oil in the fruit of four olive cultivars during the period of measurements .

Cultivars / Month of measurement	Chemlali (%)	Dekel (%)	Khastaui (%)	Khuderi (%)
May	0.0	0.0	0.0	0.0
June	300	144.44	164.29	347.62
July	69.12	109.09	86.49	22.34
August	23.30	40.33	33.41	14.43

Concerning oil content data of ripe fruits the averages of oil percentage ranged from 12.91% in Dekel to 18.41% in Khastaui cultivars (Table 14). Khastaui cultivar recorded significant increase in oil percentage of fruit as compared to the remaining cultivars. The averages of oil yield of tree and oil productivity of hectare ranged from 1.8391 kg and 0.7356 tons in Chemlali to 2.0788 kg and 0.8315 tons in Khuderi cultivars respectively (Table 14). No significant differences were found between cultivars in regard to oil yield of tree and oil productivity of hectare.

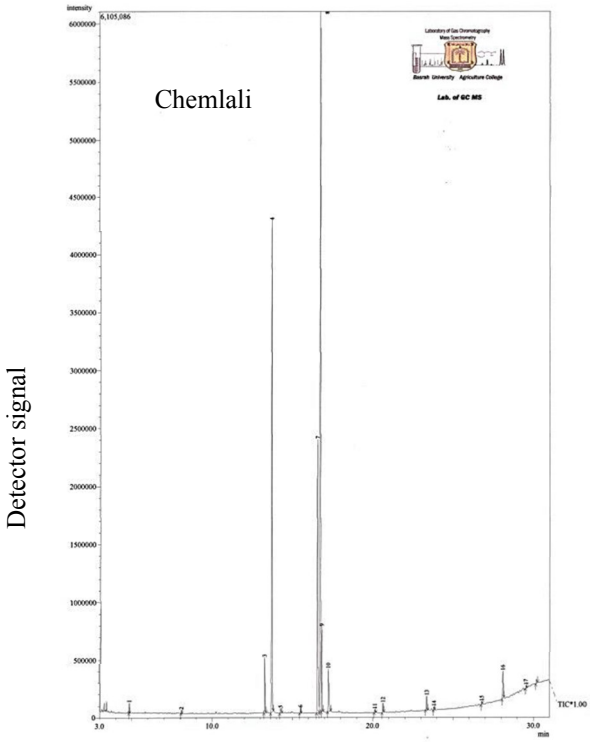
Table 14: oil percentage of mature fruit, oil yield of tree and oil productivity of hectare of four olive cultivars.

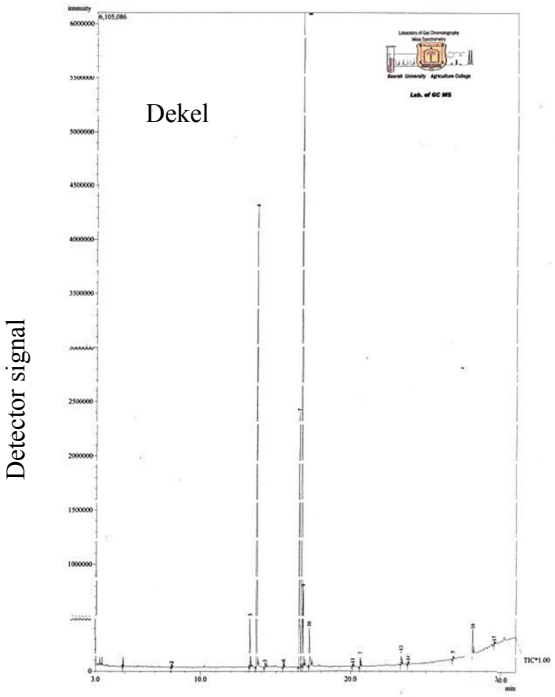
***Each value represents combined averages of four replicates for the years of measurements.**

Cultivar	% Oil (100g fruit $^{-1}$)	Oil yield (kg. tree^{-1})	Oil productivity (ton. hectare^{-1})
Chemlali	14.18*	1.8391	0.7356
Dekel	12.91	1.9240	0.7696
Khastaui	18.41	1.8495	0.7398
Khuderi	13.16	2.0788	0.8315
LSD P≤ 0.05	2.108	NS	NS

FATTY ACID COMPOSITION

The fatty acid analysis of olive fruit oils by GC-MS were shown in Figure (1). As listed in Tables (15,16,17 and 18), there were small differences among the studied olive cultivars considering their fatty acid composition. The most abundant fatty acid in all olive cultivars was oleic acid (18:1) ranging from 40.26% in Khuderi to 48.20% in Khastaui cultivars. Palmitic acid (16:0) content was lowest (23.03%) in Khastaui and highest (28.34%) in Dekel cultivars Linoleic acid (18:2) content varied from 9.61% in Khastaui to 15.75 in Dekel cultivars. Palmitoleic acid (16:1) and stearic acid (18:0) were from 2.93% and 2.04% in Khastaui to 3.18% and 2.45% in Dekel cultivars respectively.


Chemlali
Detector signal
Column retention time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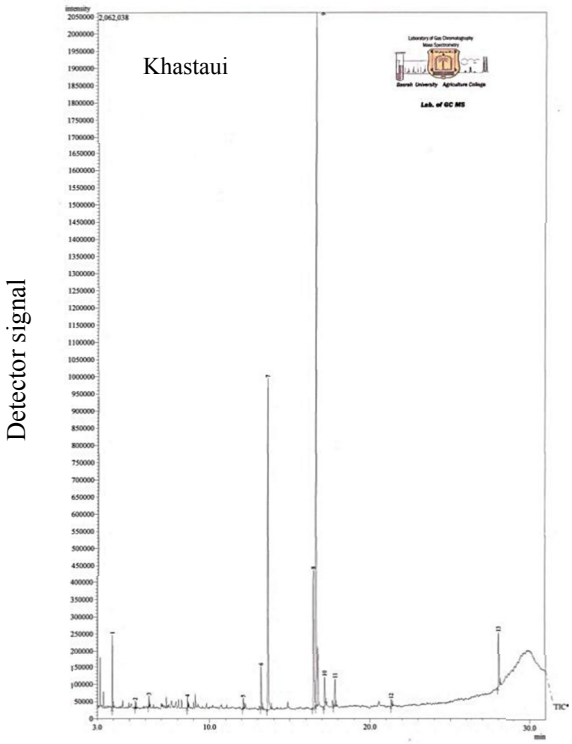
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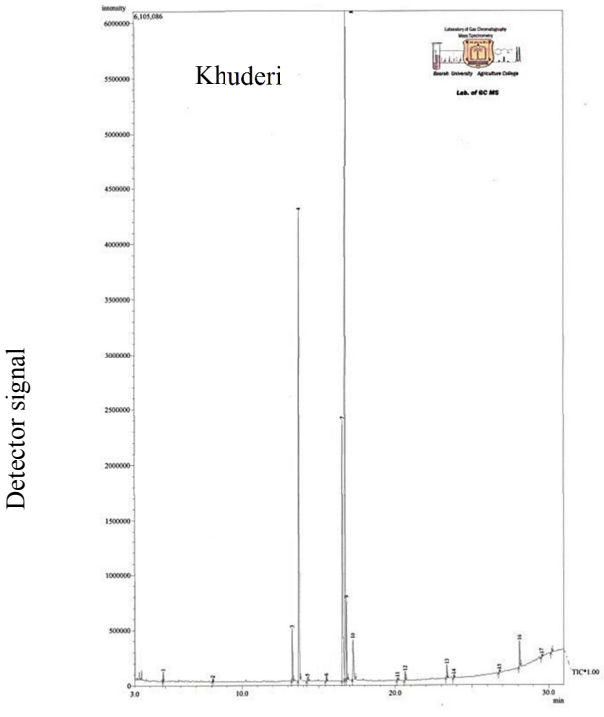
Khuderi
Detector signal
Column retention time

Table 15: Fatty acid composition (%) of mature fruit oil in Chemlali olive cultivar.

Peak	Fatty acid	Formula	Mol Weight	R.Time	Composition (%)
3	Palmitoleic acid, methyl ester	C17 H32 O2	268	13.281	3.17
4	Palmitic acid, methyl ester	C17 H34 O2	270	13.720	28.28
7	Linoleic acid, methyl ester	C19 H34 O2	294	16.564	15.72
8	Oleic acid, methyl ester	C19 H36 O2	296	16.735	40.27
10	Stearic acid, methyl ester	C19 H38 O2	298	17.251	2.44

Table 16: Fatty acid composition (%) of mature fruit oil in Dekel olive cultivar.

Peak	Fatty acid	Formula	Mol Weight	R.Time	Composition (%)
3	Palmitoleic acid, methyl ester	C17 H32 O2	268	13.281	3.18
4	Palmitic acid, methyl ester	C17 H34 O2	270	13.720	28.34
7	Linoleic acid, methyl ester	C19 H34 O2	294	16.564	15.75
8	Oleic acid, methyl ester	C19 H36 O2	296	16.735	40.37
10	Stearic acid, methyl ester	C19 H38 O2	298	17.251	2.45

Table 17 : Fatty acid composition (%) of mature fruit oil in Khastaui olive cultivar.

Peak	Fatty acid	Formula	Mol Weight	R.Time	Composition (%)
6	Palmitoleic acid, methyl ester	C17 H32 O2	268	13.211	2.93
7	Palmitic acid, methyl ester	C17 H34 O2	270	13.648	23.03
8	Linoleic acid, methyl ester	C19 H34 O2	294	16.487	9.61
9	Oleic acid, methyl ester	C19 H36 O2	296	16.656	48.20
10	Stearic acid, methyl ester	C19 H38 O2	298	17.176	2.04

Table 18 : Fatty acid composition (%) of mature fruit oil in Khuderi olive cultivar.

Peak	Fatty acid	Formula	Mol Weight	R.Time	Composition (%)
3	Palmitoleic acid, methyl ester	C17 H32 O2	268	13.281	3.16
4	Palmitic acid, methyl ester	C17 H34 O2	270	13.720	28.26
7	Linoleic acid, methyl ester	C19 H34 O2	294	16.564	15.70
8	Oleic acid, methyl ester	C19 H36 O2	296	16.735	40.26
10	Stearic acid, methyl ester	C19 H38 O2	298	17.251	2.43

The variations in oil content and fatty acid composition of the studied olive cultivars may due to genotype effect, environment such as temperature during fruit growth, degree of maturation, crop season and cultural practices. These findings were in line with those of Tunisian olive oils (Samia Dabbou et al , 2011) and those of Libyan olive oils (Benkhayal et al, 2014).

It would be worth noting that most oil synthesis occurs in the mesocarp cells and the final fruit oil content depends on the amount of mesocarp and the percent oil content (Tombesi, 1994; Proietti, 2003). Therefore, data of olive fruit anatomy are of particular interest as these may contribute to the account of oil accumulation in the fruits of the studied genotypes.

ANATOMICAL CHARACTERS

Data concerning the anatomy of pericarp and mesocarp of mature olive fruit in the samples were shown in Figures (2 and 3) and Table (19).

The cuticle was covered by epicuticlar wax. The cuticle was uniform in most of the fruits in all cultivars except that of Khastaui cultivar which became non-uniform and very thick (Figure 2: E-H). The average thickness of cuticle layer ranged from 11.86µm in Khuderi to 27.75 µm in Khastaui cultivars. Khastaui differed significantly from the remaining cultivars, and Chemlali and Dekel from Khuderi cultivars in respect of cuticle layer thickness. Average thickness of epidermis layer varied from 33.90 µm in Chemlali to 47.5 µm in Khastaui cultivars. Khastaui cultivar had significantly higher epidermis layer thickness than that of Chemlali and Khuderi cultivars. Dekel cultivar differed significantly from Chemlali cultivar in this respect. Average thickness of lower epidermis layer was from 94.16 µm in Chemlali to 172.5 µm in Dekel cultivars. Chemlali cultivar was significantly different in lower epidermis layer thickness as compared to the other cultivars. Khastaui and Khuderi cultivars were also differed significantly from Chemlali cultivar in this respect.

Average sclernchyma layer thickness ranged from 42.50 µm in Dekel to 69.37 µm in Khastaui cultivars. Khastaui cultivar was significantly different in sclernchyma layer thickness as compared to the remaining cultivars. Khuderi differed significantly from Chemlali and Dekel cultivars in respect of sclernchyma layer thickness. Mesocarp cells were varied in shape and arranged loosely with many empty cavities. Vascular bundles were scattered sporadically among the various shaped cells.Some mucilage cavities stained deep red ,whereas

vascular bundles stained purple .Average number of cells of inner mesocarp ranged from 119.0 cells mm^{-2} in Khuderi to 214.5 cells mm^{-2} in Dekel cultivars . Chemlali and Dekel cultivars were significantly higher than the other two cultivars in this respect. Average cell length and width were lowest (146.40 and 103.12) µm in Dekel and Chemlali cultivars respectively and highest (255.62 and 195.62) µm in Chemlali and Khastaui cultivars respectively.

There were significant differences among cultivars regarding cell length. Chemlali differed significantly from the other cultivars, Khuderi from Dekel and Khastaui, and Khastaui from Dekel cultivars in respect of cell length. Regarding cell width, Khastaui differed significantly from the remaining cultivars ,Khuderi from Chemlali and Dekel ,and Dekel from Chemlali cultivars .Average number of vascular bundles varied from 6.0 in Khastaui to 11.33 in Chemlali cultivars. Chemlali and Khuderi cultivars recorded significant increases over the other two cultivars in this respect. Averege vascular bundle thickness ranged from 37.0 µm in Dekel to 50.33 µm in Khastaui cultivars. All olive cultivars were significantly different from Dekel cultivar in this respect. No significant differences were found among Chemlali, Khastaui and Khuderi cultivars regarding vascular bundle thickness.

The observed variations in the internal structures of olive fruits including the measured thickness of pericarp may due to genetic differences of the studied cultivars and effect of the dominant environmental conditions of the region (Xin *et al*., 2006). The anatomical description of olive fruits was in line with that reported by Martin and Sabbett (2005).

Table 19: Anatomical characters of mature fruits of Chemlali, Dekel, Khastaui and Khuderi olive cultivars.

Cultivar	Cuticle thickness (µm)	Epidermis thickness (µm)	Lower epidermis thickness (µm)	Sclernchyma layer thickness (µm)	No of cells (mm^{-2})	Cell length (µm)	Cell width (µm)	No. vascular bundles (mm^{-2})	Vascular bundle thickness (µm)
Chemlali	(11.2-18.2) 16.22	(25.11-50.2) 33.90	(60.5-125) 94.16	(25-62.77) 42.55	(120-150) 133.33	(157.5-375.88) 255.62	(60.33-132) 103.12	(8-16) 11.33	(25-60) 44.5
Dekel	(14.2-18.51) 17.0	(35.5-62.5) 43.21	(157.5-187.5) 172.5	(25-75.12) 42.50	(162-270) 214.5	(62.5-345) 146.40	(62.5-157.5) 114.37	(6-12) 8.0	(33-40) 37.0
Khastaui	(22.5-43.19) 27.75	(32.5-64.22) 47.5	(95.4-125) 115.44	(62.5-82.5) 69.37	(90-150) 120.0	(157.5-375.66) 221.12	(125.6-250) 195.62	(4-9) 6.0	(38-75) 50.33
Khuderi	(9.10-15.72) 11.86	(30.2-55.22) 38.92	(62.5-187.5) 109.37	(20-75.32) 51.87	(78-140) 119.0	(50.21-500) 232.50	(95.1-375) 185.32	(6-18) 10.0	(25-50) 45.8
LSD P≤ 0.05	2.826	6.167	7.8	7.28	5.669	5.454	4.663	3.262	7.37

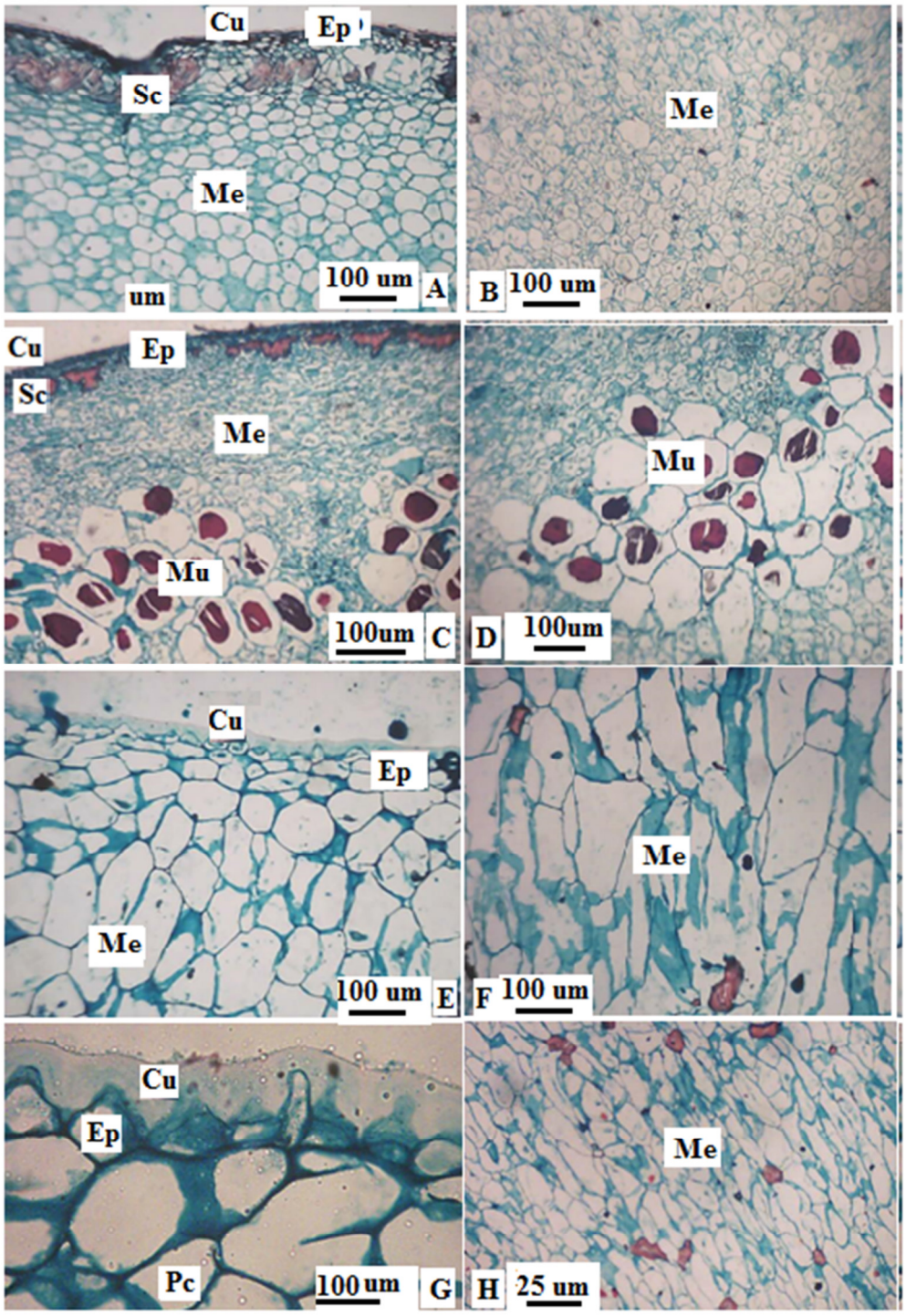

Figure 2: Anatomy of fruit pericarp and mesocarp of olive cultivars as observed via light microscopy. A-D: Dekel: E-H, Khastaui. Abbreviations: Cu, cuticle; Ep, epidermis; Sc, Sclerenchyma layer; Me, mesocarp layer; Mu, Musilage; Pc, Parenchyma cells.

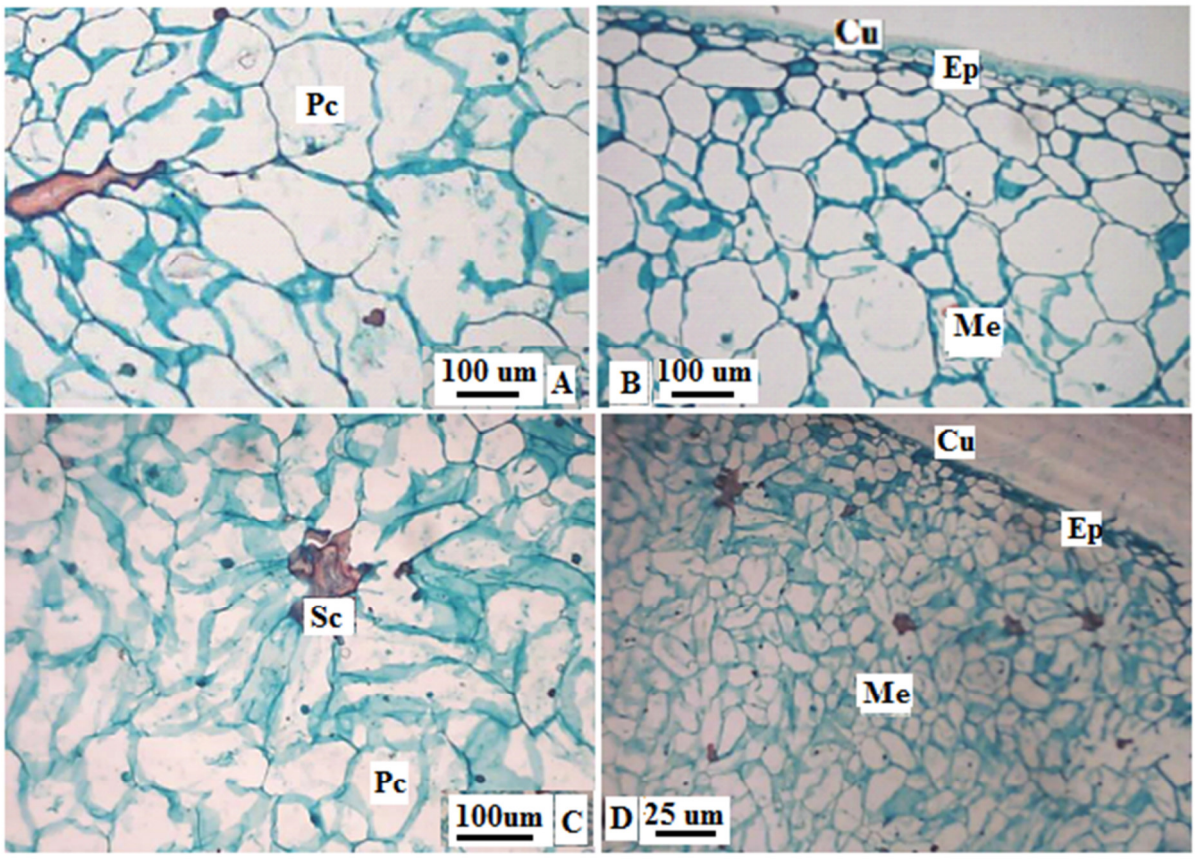

Figure 3: Anatomy of fruit pericarp and mesocarp of olive cultivars as observed via light microscopy. A&B: Chemlali: C &D, Khuderi. Abbreviations: Cu, cuticle; Ep, epidermis; Sc, Sclerenchyma layer; Me, mesocarp layer; Mu, Musilage; Pc, Parenchyma cells.

Conclusion

This study revealed valuable information on the performance of the studied olive cultivars in Basrah region. Olive cultivars of low chilling requirements can grow successfully and bearing fruits of good quality.

It was found that late Summer and early Autumn seem to be an optimum fruit harvesting period for table and oil production in this species.

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