Pak. J. Bot., 51(5): 1775-1781, 2019. DOI: http://dx.doi.org/10.30848/PJB2019-5(42)

PERFORMANCE AND OIL QUALITY OF SEVEN OLIVE CULTIVARS UNDER HIGH DENSITY PLANTING SYSTEM IN NORTHERN CYPRUS

SERHAT USANMAZ[1], İBRAHIM KAHRAMANOĞLU[1*], TURGUT ALAS[1] AND VOLKAN OKATAN[2]

[1]*Faculty of Agricultural Sciences and Technologies, European University of Lefke, Lefke, Northern Cyprus via Mersin 10 Turkey*
[2]*Faculty of Agriculture, Uşak University, Uşak, Turkey*
[*]*Corresponding author's email: ibrahimcy84@yahoo.com, ikahramanoglu@eul.edu.tr*

Abstract

Olive (*Olea europea* L.) plays an important role in the Mediterranean agriculture where olive oil is the fundamental fat supply in the Mediterranean diet. Olive tree has been found within the habitats of Cyprus for a long time but, most of the olive cultivars are wild with low yield and low quality. High-density plantations are key factor for improving olive tree productivity and selection of the appropriate cultivar is crucial. The aim of current study was to test the performance and oil quality of five commercial clones cv. 'Arbequina', cv. 'Arbosana', cv. 'Sikitita', cv. Koroneiki and cv. 'Tosca' grown in high-density systems in Northern Cyprus in comparison with two local cultivars cv. 'Kato Drys' and cv. 'Klirou'. The experimental studies were conducted in Guzelyurt in Northern Cyprus during 5 sequential crop years from 2013 (2nd growing year) to 2017 (6th growing year). Seedlings of commercial clones were planted with a pattern of 4 x 2 m (1250 trees ha^{-1}) and local cultivars with a pattern of 5 x 5 m (400 trees ha^{-1}). Results indicated that Arbequina, Arbosana and Koroneiki are the most precocious cultivars which bore fruits in the second year after planting and had the highest cumulative olive and olive oil yield in 6 successive growing seasons. However, Arbequina cultivar was also found to have higher free fatty acid contents (% oleic acid) than the IOC limit (0.8% oleic acid) for extra virgin olive oil.

Key words: Olive yield; Oil yield; Adaptation; Mediterranean climate; Free fatty acidity; Peroxide value.

Introduction

The olive (*Olea europea* L.) tree is an important evergreen tree in the Mediterranean basin (Meikle, 1977); and is characterized as a drought tolerant species (Orgaz & Fereres, 1997). Olive fruits are rarely used in their harvested form due to intense bitterness and are either consumed as oil or table olives (Medeiros, 2001). Olive oil is the fundamental fat supply in the Mediterranean diet which is known as very beneficial against cardiovascular disease (Serra-Majem *et al*., 2003). Worldwide popularity and consumption of olive derived products has been showing a considerable increase, especially in the last decades, mainly because of its scientifically recognoized health benefits (Menendez *et al*., 2006; Pérez-Jiménez *et al*., 2007; Ocakoglu *et al*., 2009). Olive tree has been found within the habitats of Cyprus since the Neolithic period (6th millennium BC) (Egoumenidou, 2005). However, most of the olive cultivars are wild with low yield and low oil quality. Traditional olive production in Cyprus remained at the pre-industrial level at least until the mid-20th century.

Extra-virgin olive oil (EVOO) composition, including oleic acid, determines the intrinsic quality of olive oils (Covas *et al*., 2006). Olive yield and oil quality are greatly affected by olive cultivar (Tura *et al*., 2007) geographical production area (Temime *et al*., 2006; Usanmaz *et al*., 2018), climate (Cerretaini *et al*., 2006; Koç *et al*., 2018; Okatan & Çolak, 2019) and production system and process (Patumi, 1999; Lozano-Sanchez *et al*., 2010). In the last three decades, several studies suggested denser plantations with appropriate varieties having high yield per area and with suitability for continuous mechanical harvesting (Tous *et al*., 2010; Farinelli *et al*., 2012). Many of the traditional olive plantations, not only in Cyprus but in the Mediterranean basin, were with few plants per hectare, without irrigation and low yield (Proietti *et al*., 2012), unlike high-density plantations with high number of plants per hectare, with irrigation and high yield (Connor *et al*., 2014). The selection of the appropriate olive cultivar is crucially important for high-density olive groves (Abenoza *et al*., 2014). The varieties should have characteristics to be suitable for high density production, i.e. flexible branches, early yielding and compact growth (Connor *et al*., 2014). Most traditional cultivars in Cyprus (e.g. 'Kato Drys' and 'Klirou') are not adapted to high-density orchards (Anestiadou *et al*., 2017). Researchers around the world reported that Spanish cv. 'Arbequina', cv. 'Arbosana' and cv. 'Sikitita' (Proietti *et al*., 2012; Abenoza *et al*., 2014; Talhaoui *et al*., 2014), Greece cv. Koroneiki (Allalout *et al*., 2011) and Italian cv. 'Tosca' (Abenoza *et al*., 2014) showed easy adaptation to high-density plantations and widely used worldwide. The aim of current study was to test the performance and oil quality of five commercial clones grown in high-density systems in Northern Cyprus in comparison with two local cultivars.

Experimental studies

Experimental field and cultivation: The present study was conducted in an experimental orchard, located at the Research and Application Farm of the European University of Lefke, near Guzelyurt city (35°11'10.54" N, 32°58'20.84" E, altitude 41 m a.s.l.). The orchard was established at the beginning of May in 2012. Seedlings of *Olea europea* L. cv. 'Arbequina', cv. 'Arbosana', cv. 'Tosca', cv. 'Sikitita' and cv. 'Koroneiki' were planted with a pattern of 4 x 2 m (1250 trees ha^{-1}). Two local cultivars of cv. 'Kato Drys' and cv. 'Klirou' were planted with a pattern of 5 x 5 m (400 trees ha^{-1}). The studies continued for 5 sequential crop years from 2013 (2nd growing year) to 2017 (6th growing year). The site was characterized by Mediterranean climate with relatively hot and dry summers and mild and rainy winters with a mean of 346.74 mm rainfall (Table 1). Plant materials of present study were all provided by the Crop Husbandry Project supported by the European Commission and the cv. 'Sikitita' is a protected cultivar obtained by the University of Córdoba and the IFAPA.

The soil of the experimental orchard was a clay loam with a 7.5 pH and 2.5% organic matter. Experiments were conducted in randomized complete block design with 3 replicates. Each replication consisted of 30 trees where 24 from each replication were used for the experimental measurements. Single trunk training system was used for all cultivars. Irrigation was performed by drip irrigation system with double line per row and 4 L hour^{-1} emitters placed at 0.5 m intervals along the line. The orchard was irrigated through a drip irrigation system with 5 days intervals from May to October during the growing seasons. Daily irrigation volumes per tree are given in Table 2 as monthly basis.

Table 1. Meteorological data for study area as an average recorded along studying years.

Months	Average minimum temp. (C)	Average maximum temp. (C)	Average rainfall (mm)
January	7.06	16.36	74.53
February	7.82	17.47	52.41
March	9.14	19.43	30.77
April	11.64	22.78	18.39
May	15.18	27.19	14.37
June	19.12	31.55	5.95
July	22.92	34.03	0.65
August	22.57	35.39	1.85
September	19.55	31.44	9.94
October	15.49	27.41	16.63
November	12.26	23.08	45.89
December	8.78	18.12	75.38

Table 2. Irrigation volumes (L) of olive trees per tree & day.

Years	Months					
	May	Jun	Jul	Aug	Sep	Oct
1st year	5	5	6	6	5	5
2nd year	10	12	14	16	15	15
3rd year	20	23	26	29	25	25
4th year	35	38	41	44	40	35
5th to 7th year	40	45	50	52	48	40

Fertilization of the crops was integrated with irrigation, attempting to cover a contribution of 40-20-50 kg ha^{-1} of N-P-K respectively. Regular control of pests and diseases was performed during the experiments. Once, sometimes twice a year pesticide applications was performed for controlling olive fruit fly (*Bractocera oleae*) and very rarely one fungicide application for controlling olive leaf spot caused by *Spilocaea oleaginea*.

Data collection and oil extraction process: Harvesting of olives was performed during September to February depending on the maturity index and season (Table 3). Olive skin and pulp colours were used as a guideline for the maturity index. All 24 trees of each replication for each cultivar were hand-picked separately by professional workers. After harvesting total yield (kg tree^{-1}) was also determined.

Five plants were selected from each replication for each cultivar and 10 fruits were sampled from each plant to assess their mean weight (g), polar diameter (mm) and equatorial diameter (mm) for only 2016 and 2017. Olive oil was extracted from a bulk of olive samples per replication for each treatment by using an industrial olive mill. The malaxation temperature was 28°C for 30 min. Then the oil was then separated with a vertical centrifuge; and thus left to decant. Oil yield of each cultivar were then calculated as oil per tree (kg) and oil (% of fruit weight). Afterwards, oil samples were filtered and kept in 100 mL dark bottles at 4°C till analysis (Bourazanis *et al*., 2016). Free acidity (% oleic acid) was determined according to the ISO (International Organization for Standardization) 660 analytical method and the results expressed as % oleic acid. Peroxide value (mEq O_2 kg^{-1}) was then assessed by titration with sodium thiosulfate according to the European Union standard methods (Annex II and Annex IX of Commission Regulation EEC/2568/91).

Statistical analysis: One-way analysis of variance (ANOVA) was performed to assess the statistical significance among the tested cultivars for total yield (kg tree^{-1}), oil per tree (kg), oil (% of fruit weight), mean fruit weight (g), polar diameter (mm), equatorial diameter (mm), free acidity (% oleic acid) and peroxide value (mEq O_2 kg^{-1}). Mean separations were done with Tukey's multiple range test. The data were analysed by using SPSS 22.0 (IBM Company, New York, USA).

Results and Discussions

The three commercial olive cultivars, Arbequina, Arbosana and Koroneiki were found to be the most precocious cultivars which bore fruits in the second year. On the contrary, local cultivars Kato Drys and Klirou were found to be the latest cultivars which bear fruit in the fifth year after planting. Significant differences were observed among cultivars in all season. The highest yield (kg tree^{-1}) observed in 2015 (4th year after planting) from Koroneiki cultivar with 9.58 kg tree^{-1} and is followed by Arbequina in 2015 and 2016 with 8.75 kg tree^{-1} and Arbosana in 2016 with 8.28 kg tree^{-1} (Table 4). These three cultivars were determined as the most productive (in terms of yield tree^{-1}) cultivars. Sikitita cultivar was found to bear fruit in the third year after planting whereas Tosca was firstly harvested in fourth year after planting. All commercial cultivars showed considerable increase in the fruit yield in 2015 (4th year after planting); onwards all cultivars except Koroneiki showed slight increase or steady in fruit yield. The fruit yield of Koroneiki reduced from a mean of 9.58 kg tree^{-1} to 6.08 kg tree^{-1}. Arbequina had significantly higher accumulated yield (as a total of 5 fruit bearing seasons) and is followed by Arbosana and Koroneiki cultivars. Results also showed that local cultivars have 'on' and 'off' seasons, where commercial cultivars show steady in production. Previously Del Rio *et al.*, (2002) and Farinelli & Tombesi (2015) reported that Arbequina is a precocious cultivar, has an increasing level of fruit yield and keep yield steady when plants reach maximum canopy volume. Arbequina, Arbosana and Koroneiki cultivars are short in characteristics and very suitable for high-density planting system. On the other hand, they were reported to have similar yields (Camposeo & Godini, 2010) which support the findings of the present study.

Table 3. Harvesting dates of the cultivars for each consecutive season.

Cultivars	Years – Years after planting				
	2013 – 2nd	2014 – 3rd	2015 – 4th	2016 – 5th	2017 – 6th
Arbequina	11.12.13	22.12.14	04.12.15	18.12.16	25.11.17
Arbosana	18.12.13	28.12.14	16.12.15	25.12.16	10.12.17
Koroneiki	04.01.14	13.01.15	11.01.16	10.01.17	07.01.18
Sikitita	N/A	15.12.14	30.11.15	12.12.16	15.11.17
Toska	N/A	N/A	28.12.15	27.12.16	20.12.17
Kato Driss	N/A	N/A	N/A	7.10.16	20.09.17
Klirou	N/A	N/A	N/A	7.10.16	20.09.17

Table 4. Olive yield (kg tree^{-1}) of the compared cultivars for 5 successive growing seasons.

Cultivars	Total yield (kg tree^{-1})				
	2013 – 2nd	2014 – 3rd	2015 – 4th	2016 – 5th	2017 – 6th
Arbequina	0.06 c, D	4.65 a, C	8.75 b, A	8.75 a, A	7.78 a, B
Arbosana	0.12 b, D	4.51 a, C	8.10 c, A	8.28 b, A	7.33 ab, B
Koroneiki	0.41 a, D	4.78 a, C	9.58 a, A	6.08 e, B	6.81 c, B
Sikitita		3.10 b, D	6.47 d, B	7.69 c, A	5.58 d, C
Tosca			3.54 e, B	7.10 d, A	7.18 bc, A
Kato Drys				3.13 f, *	4.97 e, *
Klirou				2.03 g, *	4.10 f, *

Values followed by the same small letter or letters 'a, b, c' within the same column; and the same capital letter or letters 'A, B, C' within the same row are not significantly different at 5% level (Tukey's HSD multiple range test). Year data of Kato Drys and Klirou cultivars were compared with independent samples t-test; and * used to show significant differences where NS means non-significant

The oil output of compared cultivars varied from 18.27% (first harvest of Tosca in 4th year) to 25.31% (Arbosana in 4th year) (Table 5). Olive oil yield of the compared cultivars showed significant differences both among themselves and among years. Arbequina cultivar was found to have higher oil yield in early years, and then it showed slight decrease. Changes in the oil content of Arbosana cultivar is similar with Arbequina, but had higher peak level than Arbequina. Other five cultivars of the present study showed slight increase in the oil content during successive growing seasons. Oil contents of Arbequina, Arbosana and Koroneiki in present study were found to be slightly higher than the reports of Camposeo & Godini (2010) and Diez *et al*., (2016). The dishonoured performance of Arbosana in high/super high-density systems (Larbi *et al*., 2011; Diez *et al*., 2016) is reported to increase its use worldwide and begun to challenge Arbequina, the first discovered cultivar suitable for high-density planting.

Oil yield per tree (kg) is an important economic parameter for the growers. The oil per tree results of compared cultivars varied from 0.01 (first harvest of Arbequina in 2nd year) to 2.12 (Koroneiki in 4th year) (Table 6). Significant differences determined for olive oil per tree (kg) both among cultivars and growing season. The oil contents per tree (kg) of both Arbonasa, Arbequina, Koroneiki and Tosca found to be similar in the last production year, however Arbosana had the highest cumulative oil yield (kg ha^{-1}) 6 years after planting and is followed by Arbequiana and Koroneiki (Fig. 1). Local cultivars with 'on' and 'off' seasons, late fruit bearing characteristics and fewer number of plants per hectare were found to have the lowest accumulated oil yield. Cultivars of Arbosana, Arbequina and Koroneiki reported to have higher branching efficiency which improves fruit yield and accumulated oil yield (Rosati *et al*., 2013). On the other hand, both Arbosana and Koroneiki are ripening later than Arbequina (Barranco *et al*., 2005) which must be taken in to account in areas with winter frost occurrence. Olive and oil results of Koroneiki are similar with the findings of Barranco (2010) who reported high yield and high oil content.

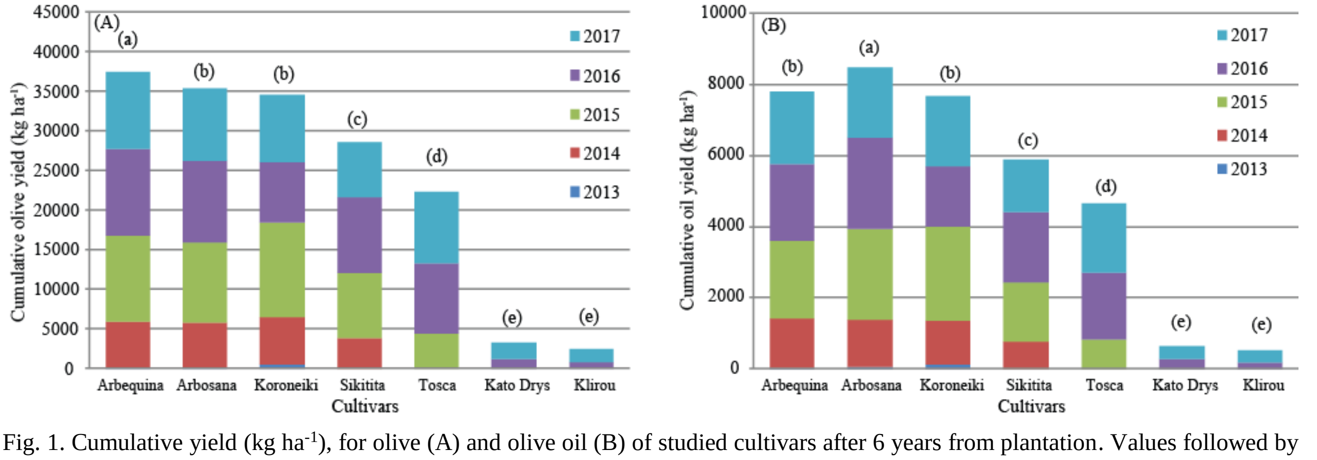

Fig. 1. Cumulative yield (kg ha^{-1}), for olive (A) and olive oil (B) of studied cultivars after 6 years from plantation. Values followed by the same letter or letters are not significantly different at 5% level (Tukey's HSD multiple range test).

Table 5. Olive oil yield (% of fruit weight) of the compared cultivars for 5 successive growing seasons.

Cultivars	Oil (% of fruit weight)				
	2013 – 2nd	2014 – 3rd	2015 – 4th	2016 – 5th	2017 – 6th
Arbequina	22.69 a, B	23.79 a, A	20.00 cd, C	19.94 c, C	20.98 b, C
Arbosana	23.48 a, AB	23.64 a, AB	25.31 a, A	24.71 a, A	21.40 ab, B
Koroneiki	20.35 b, B	20.74 b, B	22.18 b, A	22.73 b, A	22.97 a, A
Sikitita		19.58 c, B	20.58 bc, A	20.69 bc, A	21.15 ab, A
Tosca			18.27 d, B	21.37 c, A	21.76 ab, A
Kato Drys				20.17 c, NS	20.15 b, NS
Klirou				19.91 c, *	20.75 b, *

Values followed by the same small letter or letters ‘a, b, c’ within the same column; and same capital letter or letters ‘A, B, C’ within the same row are not significantly different at 5% level (Tukey’s HSD multiple range test). Year data of Kato Drys and Klirou cultivars were compared with independent samples t-test; and * used to show significant differences where NS means non-significant

Table 6. Olive oil per tree (kg) of the compared cultivars for 5 successive growing seasons.

Cultivars	Oil per tree (kg)				
	2013 – 2nd	2014 – 3rd	2015 – 4th	2016 – 5th	2017 – 6th
Arbequina	0.01 c, D	1.11 a, C	1.75 b, A	1.74 b, A	1.63 a, B
Arbosana	0.03 b, D	1.07 a, C	2.05 a, A	2.05 a, A	1.57 a, B
Koroneiki	0.08 a, E	0.99 b, D	2.12 a, A	1.38 d, C	1.56 a, B
Sikitita		0.61 c, D	1.33 c, B	1.59 c, A	1.18 b, C
Tosca			0.65 d, B	1.52 c, A	1.56 a, A
Kato Drys				0.63 e, *	1.00 c, *
Klirou				0.41 f, *	0.85 d, *

Values followed by the same small letter or letters ‘a, b, c’ within the same column; and same capital letter or letters ‘A, B, C’ within the same row are not significantly different at 5% level (Tukey’s HSD multiple range test). Year data of Kato Drys and Klirou cultivars were compared with independent samples t-test; and * used to show significant differences where NS means non-significant

Table 7. Free fatty acid (% oleic acid) of the compared cultivars for 5 successive growing seasons.

Cultivars	Free fatty acidity (% oleic acid)				
	2013 – 2nd	2014 – 3rd	2015 – 4th	2016 – 5th	2017 – 6th
Arbequina	0.20 c, D	0.70 a, C	1.17 a, A	1.08 a, B	1.11 a, AB
Arbosana	0.40 b, B	0.30 c, C	0.30 e, C	0.55 c, A	0.59 c, A
Koroneiki	0.50 a, A	0.40 b, BC	0.47 d, AB	0.38 d, C	0.39 d, C
Sikitita		0.40 b, C	1.03 b, A	0.76 b, B	0.77 b, B
Tosca			0.85 c, A	0.77 b, A	0.83 b, A
Kato Drys				0.39 d, NS	0.38 d, NS
Klirou				0.42 d, NS	0.45 d, NS

Values followed by the same small letter or letters ‘a, b, c’ within the same column; and same capital letter or letters ‘A, B, C’ within the same row are not significantly different at 5% level (Tukey’s HSD multiple range test). Year data of Kato Drys and Klirou cultivars were compared with independent samples t-test; and * used to show significant differences where NS means non-significant

International Olive Council (IOC) and European Commission determined the standards for extra virgin olive oil. The standard for free fatty acid (% oleic acid) is < 0.8% and for peroxide value is < 20 mEq O_2 kg^{-1} oil (Mailer & Beckingham, 2006; Anon., 1991, Anon., 2011). Free fatty acid (FAA) might be a good indicator of the longevity of olive oil, where higher the FAA, lower the storage duration. There were slight to high year-to-year fluctuations in the FAA content of the cultivars. FAA of Arbequina showed considerable increase during successive growing seasons and after fourth year, FAA values exceeded the upper limit determined by IOC for extra virgin olive oil (Table 7). Sikitita and Tosca cultivars also showed higher FAA contents than the IOC limit in some seasons. The FAA levels of Arbosana, Koroneiki, Kato Drys and Klirou cultivars were within the limits established by IOC and EUC, in all successive growing seasons. Oil acidity is reported to be variable depending on the climatic conditions and increasing as air temperature decreases (Dag *et al*., 2011; Ceci *et al*., 2017; Rodrigues *et al*., 2018). In a similar study in Spain FAA of Arbequina was noted as 0.08±0.01 (Reboredo-Rodriguez *et al*., 2015) where in Italy FAA was reported as 0.20±0.0 (Farinelli & Tombesi, 2015).

Peroxide value (PV) evaluates the hydroperoxides content and is a crucial test which growers should do on every batch of their oil. PV of all cultivars in all season was found to be much lower than the IOC limit (20 mEq O_2 kg^{-1}) oil (Table 8). The results are in accordance with the findings of Farinelli & Tombesi (2015) and Reboredo-Rodriguez *et al*., (2015) for Arbequina and findings of Bourazanis *et al*., (2016) for Koroneiki. PV values of Tosca were found to be lower than the findings of Abenoza *et al*., (2014) but still in the limits of IOC. The PV values of Tosca and two local cultivars were found to be significantly higher than the other cultivars; and higher than 10. Mailer & Beckingham (2006) reported that PV values higher than 10 may be considered not good for long shelf life. According to both the FAA and PV values, it can be concluded that Arbosana and Koroneiki cultivars are best for extra virgin olive oil production and the oils of those cultivars were expected to be suitable for long storage. These two cultivars were also the ones with high olive and oil yield with high cumulative yields.

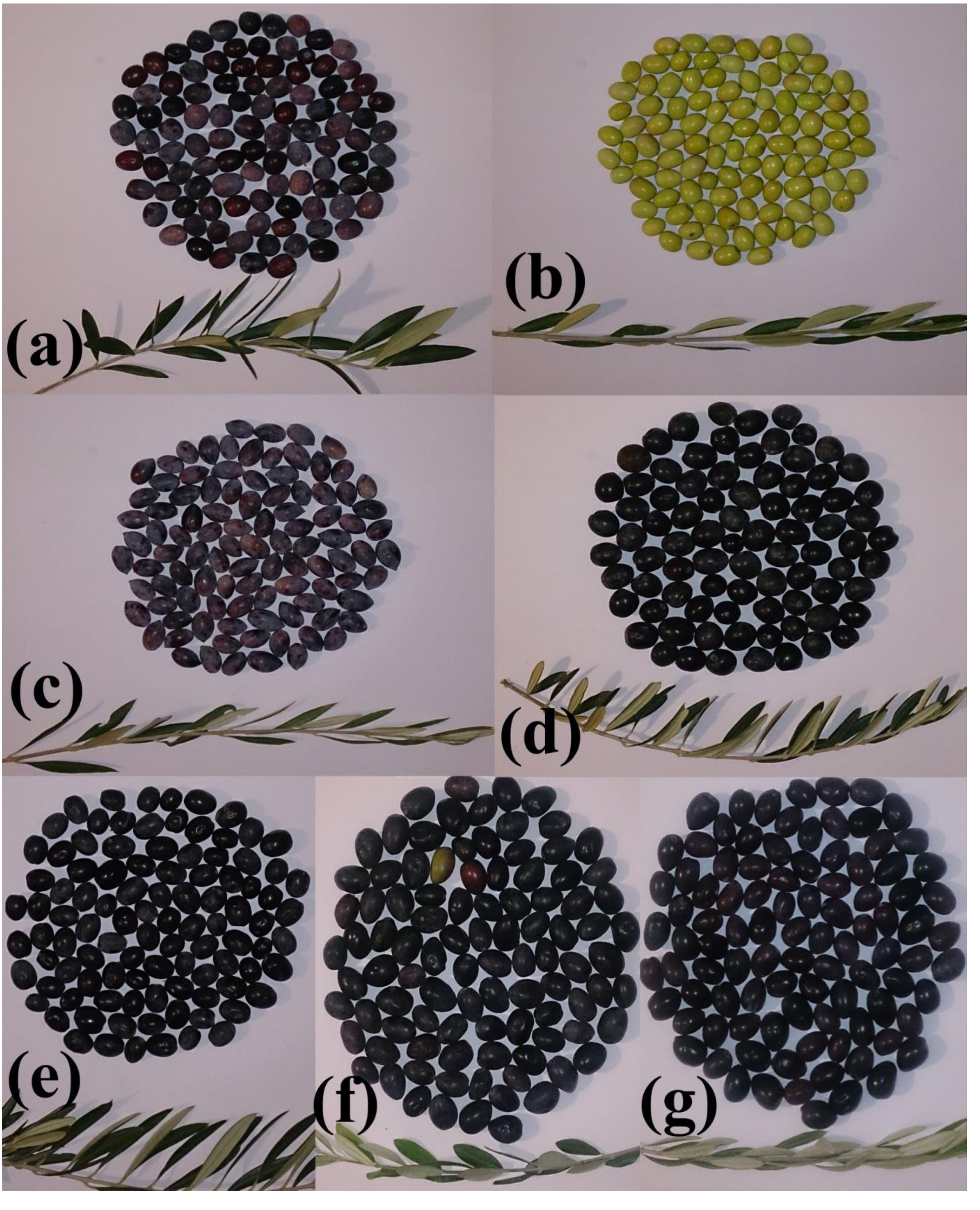

Fig. 2. Fruits of the tested olive cultivars; a) Arbequina, b) Arbosana, c) Koroneiki, d) Sikitita, e) Tosca, f) Kato Drys and g) Klirou.

Individual fruit weight results showed significant differences among cultivars, but only Arbequina cultivar was found to have significant difference for the years 2016 and 2017 (Table 9). The fruit weight of Kato Drys was found to be higher than all other tested cultivars and is followed by Klirou and Sikitita. Koroneiki cultivar (with the third highest cumulative olive yield kg ha^{-1}) found to have the lowest individual fruit weight and followed by Arbequina and Tosca. The Arbosana cultivar, which had the second highest cumulative olive yield (kg ha^{-1}) and highest cumulative olive oil yield (kg ha^{-1}) found to have median fruit weight, when comparing with other tested cultivars (Fig. 2). There is very little study about the polar and equatorial diameters of olive cultivars. As expected, polar diameter were found to be higher than the equatorial diameters. The polar and equatorial diameters of Arbequina and Tosca are similar with the findings of Abenoza *et al*., (2014).

Table 8. Peroxide value (mEq O_2 kg^{-1}) of the compared cultivars for 5 successive growing seasons.

Cultivars	Peroxide value (mEq O_2 kg^{-1})				
	2013 – 2nd	2014 – 3rd	2015 – 4th	2016 – 5th	2017 – 6th
Arbequina	7.04 a, A	6.04 b, A	6.10 bc, A	6.59 e, A	6.66 de, A
Arbosana	5.15 a, BC	5.10 c, C	5.25 c, B	5.62 g, A	5.62 f, A
Koroneiki	6.07 a, BC	5.99 b, C	6.06 bc, C	6.24 f, A	6.23 e, AB
Sikitita		6.84 a, A	7.94 ab, A	7.19 d, A	7.22 d, A
Tosca			8.76 a, B	10.57 c, A	10.58 c, A
Kato Drys				11.22 b, *	11.88 b, *
Klirou				12.60 a, *	12.92 a, *

Values followed by the same small letter or letters 'a, b, c' within the same column; and same capital letter or letters 'A, B, C' within the same row are not significantly different at 5% level (Tukey's HSD multiple range test). Year data of Kato Drys and Klirou cultivars were compared with independent samples t-test; and * used to show significant differences where NS means non-significant

Table 9. Mean fruit weight (g), polar fruit diameter (mm) and equatorial fruit diameter (mm) of the compared cultivars for 2016 and 2017 growing seasons.

Cultivars	Mean fruit weight (g)		Polar diameter (mm)		Equatorial diameter (mm)	
	2016	2017	2016	2017	2016	2017
Arbequina	1.87 c, *	1.55 c, *	15.12 e, NS	14.24 d, NS	13.21 c, NS	12.51 b, NS
Arbosana	2.20 c, NS	1.98 c, NS	16.66 de, NS	15.37 cd, NS	13.12 c, NS	12.20 b, NS
Koroneiki	1.09 c, NS	1.10 c, NS	17.86 cd, NS	17.65 bc, NS	11.65 c, NS	11.57 b, NS
Sikitita	3.95 b, NS	3.57 b, NS	19.59 c, NS	18.71 b, NS	17.84 b, NS	17.17 a, NS
Tosca	1.89 c, NS	1.99 c, NS	16.22 de, NS	15.56 cd, NS	12.88 c, NS	12.40 b, NS
Kato Drys	6.47 a, NS	5.29 a, NS	26.25 a, NS	25.33 a, NS	19.64 a, NS	18.80 a, NS
Klirou	4.75 b, NS	4.23 ab, NS	24.02 b, NS	23.30 a, NS	18.22 ab, NS	17.50 a, NS

Values followed by the same small letter or letters 'a, b, c' within the same column are not significantly different at 5% level (Tukey's HSD multiple range test). Comparison of the years within the same row were performed with independent samples t-test; and * used to show significant differences where NS means non-significant

Conclusions

Present work attempts to evaluate the long-term performance of Arbequina, Arbosana, Koroneiki, Sikitita, Tosca, Kato Drys and Klirou olive cultivars in Northern Cyprus with Mediterranean climate, characterized by its extreme temperature differences between day and night. Present study indicates that Arbequina, Arbosana and Koroneiki are suitable to be trained high-density in Northern Cyprus having Mediterranean climate which had better productive behaviour than Sikitita, Tosca, Kato Drys and Klirou. These three commercial olive cultivars were found to be the most precocious cultivars which started giving fruits in the second year after planting and had the highest cumulative olive and olive oil yield in 6 successive growing seasons. Arbosana with slightly higher oil content (% of fruit weight) was found to have higher oil yield (kg ha^{-1}) than the others. Results also showed that local cultivars; Kato Drys and Klirou, have 'on' and 'off' seasons, where commercial cultivars show steady in production. Arbequina cultivar found to have higher free fatty acid contents (% oleic acid) in Cyprus climate which moves it out to the range of extra virgin olive oil category defined by International Olive Council. Colder nights of Northern Cyprus might be the reason for the increase in the acidity of Arbequina and it is not suggested for the growers aiming to produce extra virgin olive oil. On the other hand, Arbosana and Koroneiki are ripening later than Arbequina and this characteristics must be taken account in areas with winter frost occurrence.

References

Abenoza, M., M. Benito, R. Oria and A.C. Sanchez-Gimeno. 2014. Quality characterization of the olive oil from var. Tosca 07 grown in a commercial high density orchard. *J. Am. Oil. Chem. Soc.*, 91: 613-622.

Allalout, A., D. Krichene, K. Methenni, A. Taamalli, D. Daoud and M. Zarrouk. 2011. Behavior of super-intensive Spanish and Greek olive cultivars grown in northern Tunisia. *J. Food Biochem.*, 35: 27-43.

Anestiadou, K., N. Nikoloudakis, M. Hagidimitriou and A. Katsiotis. 2017. Monumental olive trees of Cyprus contributed to the establishment of contemporary olive germplasm. *Plos One*, 12(11): e0187697

Anonymous. 1991. European Union Commission Regulation (EEC) No 2568/91 of 11 July 1991 on the characteristics of olive oil and olive-residue oil and on the relevant methods of analysis.

Anonymous. 2011. European Union Commission Regulation (EU) No 61/2011 of 24 January 2011 amending Regulation (EEC) No 2568/91 on the characteristics of olive oil and olive-residue oil and on the relevant methods of analysis.

Barranco, D. 2010. Varieties and rootstocks. In: (Eds.): Barranco, D., R. Fernández-Escobar and L. Rallo. *Olive Growing*. Juntade Andalucia and Mundi-Prensa, Madrid, pp. 59-82.

Barranco, D., I. Trujillo and L. Rallo. 2005. Elaiografía Hispanica. In: (Eds.): Rallo, L., D. Barranco, J.M. Caballero, C. Del Rio, A. Martin, J. Tous and I. Trujillo. *Variedades de Olivoen España*. Mundi-Prensa, Madrid, pp. 45-231.

Bourazanis, G., P.A. Roussos, I. Argyrokastritis, C. Kosmas and P. Kerkides. 2016. Evaluation of the use of treated municipal waste water on the yield, oil quality, free fatty acids' profile and nutrient levels in olive trees cv Koroneiki, in Greece. *Agr. Water Manag.*, 163: 1-8.

Camposeo, S. and A. Godini. 2010. Preliminary observations about the performance of 13 varieties according to the super high density oliveculture training system in Apulia (southern Italy). *Adv. Hort. Sci.*, 24(1): 16-20

Ceci, L.N., S.B. Mattar and A.A. Carelli. 2017. Chemical quality and oxidative stability of extra virgin olive oils from San Juan province (Argentina). *Food Res. Int.,* 100: 764-770.

Cerretaini, L., A. Bendini, A. Del Caro, A. Piga, V. Vacca, M.F. Caboni and T.G. Toschi. 2006. Preliminary characterization of virgin olive oils obtained from different cultivars in Sardinia. *Eur. Food Res. Technol.,* 222: 354-361.

Connor, D.J., M. Gómez-del-Campo, M.C. Rousseaux and P.S. Searles. 2014. Structure, management and productivity of hedgerow olive orchards: a review. *Sci. Hort.,* 169: 71-93.

Covas, M.I., K. Nyyssönen, H.E. Poulsen, J. Kaikkonen, H.J.F. Zunft, H. Kiesewetter, A. Gaddi, R. De La Torre, J. Mursu, H. Bäumler, S. Nascetti, J.T. Salonen, M. Fitó, J. Virtanen and J. Marrugat. 2006. The effect of polyphenols in olive oil on heart disease risk factors: A randomized trial. *Ann. Intern. Med.,* 145(5): 333-341.

Dag, A., Z. Kerem, N. Yogev, I. Zipori, S. Lavee and E. Ben-David. 2011. Influence of time of harvest and maturity index on olive oil yield and quality. *Sci. Hort.,* 127: 358-366.

Del Rio, C., M.D. García-Fernández and J.M. Caballero. 2002. Variability and classification of olive cultivars by their vigour. *Acta Hort.,* 586: 229-232.

Diez, C.M., J. Moral, D. Cabello, P. Morello, L. Rallo and D. Barranco. 2016. Cultivar and tree density as key factors in the long-term performance of super high-density olive orchards. *Front. Plant Sci.,* 7: 1226.

Egoumenidou, E.R. 2005. The olive tree and olive oil in the traditional life of Cyprus. Cyprus Today. (http://www.aboutcyprus.org.cy/en/the-olive-tree-and-olive-oil-in-the-traditional-life-of-cyprus) (Accessed on 26th of August, 2018).

Farinelli, D. and S. Tombesi. 2015. Performance and oil quality of 'Arbequina' and four Italian olive cultivars under super high density hedgerow planting system cultivated in central Italy. *Sci. Hort.,* 192: 97-107.

Farinelli, D., M. Ruffolo, M. Boco and A. Tombesi. 2012. Yield efficiency and mechanical harvesting with trunk shaker of some international olive cultivars. *Acta Hort.,* 949: 379-384.

Koç, M., H. Çetinkaya and K. Yıldız. 2018. A research on recent developments and determination of the potential of olive in Kilis, Turkey. *Int. J. Agri. Fores. & Life Sci.,* 2(2): 185-188.

Larbi, A., M. Ayadi, A. Ben Dhiab, M. Msallem and J.M. Caballero. 2011. Olive cultivars suitability for high-density orchards. *Span. J. Agric. Res.,* 9: 1279.

Lozano-Sánchez, J., A. Segura-Carretero, J.A. Menendez, C. Oliveras-Ferraros, L. Cerretani and A. Fernández-Gutiérrez. 2010. Prediction of extra virgin olive oil varieties through their phenolic profile. Potential cytotoxic activity against human breast cancer cells. *J. Agric. Food Chem.,* 58(18): 9942-9955

Mailer, R. and C. Beckingham. 2006. Testing olive oil quality: chemical and sensory methods. *Primefact*, 231: 5.

Medeiros, M.D. 2001. Olive oil and health benefits. In: (Ed.): Wildman, R.E.C. *The Handbook of Nutraceuticals and Functional Foods.* CRC Press, Boca Raton, FL, pp. 261-267.

Meikle, R.D. 1977. Flora of Cyprus. Vol. 1. The Bentham – Moxon Trust Royal Botanic Gardens, Kew.

Menendez, J.A., A., Papadimitropoulou, L. Vellon, R. Colomer and R. Lupu. 2006. A genomic explanation connecting "Mediterranean diet", olive oil and cancer: Oleic acid, the main monounsaturated fatty acid olive oil, induces formation of inhibitory "PE3 transcription factor -PEA3 DNA binding site" complexes at the Her-2/neu(erB-2) oncogenese promoter in breast, ovarian and stomach cancer cells. *Eur. J. Cancer*, 42: 2425-2432.

Ocakoglu, D., F. Tokatli, B. Ozen and F. Korel. 2009. Distribution of simple phenols, phenolic acids and flavonoids in Turkish monovarietal extra virgin olive oils for two harvest years. *Food Chem.,* 113: 401-410.

Okatan, V. and A.M. Colak. 2019. Chemical and phytochemicals content of barberry (berberis vulgaris l.) fruit genotypes from sivasli district of usak province of western turkey. *Pak. J. Bot*., 51(1): 165-170.

Orgaz, F. and E. Fereres. 1997. Riego. In: (Eds.): Barranco, D., R. Fernaandez-Escobar and L. Rallo. *El cultivo del olivo*. Mundi-Prensa, Madrid, pp. 251-271.

Patumi, M., G. D´Andria, G. Fontanazza, P. Morelli, P. Giorgio and G. Sorrentino. 1999. Yield and oil quality of intensively trained trees of three cultivars of olive (*Olea europea* L.) under different irrigation regimes. *J. Hort. Sci. Biotech.,* 74(6): 729-737.

Pérez-Jiménez, F., J. Ruano, P. Perez-Martinez, F. Lopez-Segura and J. Lopez-Miranda. 2007. The influence of olive oil on human health: not a question of fat alone. *Mol. Nutr. Food Res.,* 51: 1199-1208.

Proietti, P., L. Nasini and L. Ilarioni. 2012. Photosynthetic behavior of Spanish Arbequina and Italian Maurino olive (*Olea europaea* L.) cultivars under super-intensive grove conditions. *Photosynthetica*, 50: 239-246.

Reboredo-Rodríguez, P., C. González-Barreiro, B. Cancho-Grande, G. Fregapane, M.D. Salvador and J. Simal-Gándara. 2015. Characterisation of extra virgin olive oils from Galician autochthonous varieties and their co-crushings with Arbequina and Picual cv. *Food Chem.,* 176: 493-503.

Rodrigues, N., S. Casal, A.M. Peres, P. Baptista, A. Bento, H. Martín, M.C. Asensio-S-Manzanera and J.A. Pereira. 2018. Effect of olive trees density on the quality and composition of olive oil from cv. Arbequina. *Sci Hort.,* 238:222-233.

Rosati, A., A. Paoletti, S. Caporali and E. Perri. 2013. The role of tree architecture in super high density olive orchards. *Sci. Hortic.,* 161: 24-29.

Serra-Majem, L., J. Ngo De La Cruz, L. Ribas and J.A. Tur. 2003. Olive oil and the Mediterranean diet: beyond the rhetoric. *Eur. J. Clin. Nutr.,* 57: 2-7.

Talhaoui, N., A.M. Gómez-Caravaca, L. León, R. De La Rosa, A. Segura-Carretero and Fernández-Gutiérrez. 2014. Determination of phenolic compounds of 'Sikitita' olive leaves by HPLC-DAD-TOF-MS. Comparison with its parents 'Arbequina' and 'Picual' olive leaves. *LWT - Food Sci. Technol.,* 58(1): 28-34.

Temime, S.B., E. Campeol, P.L. Cioni, D. Daoud and M. Zarrouk. 2006. Volatile compounds from Chétoui olive oil and variations induced by growing area. *Food Chem.,* 99(2): 315-325.

Tous, J., A. Romero and J.F. Hermoso. 2010. New trends in olive orchard design for continuous mechanical harvesting. *Adv. Hort. Sci.,* 24:43-52.

Tura, D., C. Gigliotti, S. Pedo, O. Failla, D. Bassi and A. Serraicco. 2007. Influence of cultivar and site of cultivation on levels of lipophilic and hydrophilic antioxidants in virgin olive oils (*Olea europea* L.) and correlations with oxidative stability. *Sci. Hort.,* 112: 108-119.

Usanmaz, S., F. Öztürkler, M. Helvacı, T. Alas, İ. Kahramanoğlu and M.A. Aşkın. 2018. Effects of periods and altitudes on the phenolic compounds and oil contents of olives, cv. Ayvalık. *Int. J. Agri. Forest. & Life Sci.,* 2(2): 32-39.

(Received for publication 11 July 2018)