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Yield and oil quality of 'Picual' and 'Koroneiki' olive cultivars under high density planting system in Northern Cyprus

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ABSTRACT
This study aimed to determine olive and oil yield and quality of 'Picual' and 'Koroneiki' cultivars grown in high density planting systems in Northern Cyprus. The research was conducted in the city of Güzelyurt located in the western part of Northern Cyprus during 5 consecutive crop years from 2013 (2nd growing year) to 2017 (6th growing year). Planting distance of the two cultivars was adjusted as 4 x 2 m, equalling to 1250 trees ha^{-1}. Results showed that 'Koroneiki' is more promising than 'Picual' and it starts fruit bearing 2 years after planting. The 'Picual' cultivar was found to be late in fruit bearing, but its yield was noted to be significantly higher than the 'Koroneiki', where the cumulative yield of 'Picual' reached 'Koroneiki' in two years. Oil yield (% of fruit weight) of 'Koroneiki' was found to be varied from 21.02 % to 22.67 % and of 'Picual' from 18.47 % to 20.13 %. 'Picual' cultivar with less oil yield (% of fruit weight) than 'Koroneiki' noted to have higher oil per tree (kg).

Keywords:
Olive tree performance
Cumulative olive yield
Fruit weight
Free fatty acidity
Peroxide value

Kuzey Kıbrıs'ta sık dikim sisteminde yetiştirilen 'Picual' ve 'Koroneiki' zeytin çeşitlerinin meyve ve yağ verim ve kaliteleri

ÖZET
Bu çalışmanın amacı Kuzey Kıbrıs'ta sık dikim sisteminde yetiştirilen "Picual" ve "Koroneiki" çeşitlerinin zeytin ve yağ verimi ve kalitesini belirlemektir. Araştırma, Kuzey Kıbrıs'ın batısındaki Güzelyurt şehrinde, 2013'ten (2'nci büyüme yılı) 2017'ye (6'ıncı büyüme yılı) kadar devam eden 5 ardışık ürün yılı boyunca gerçekleştirilmiştir. Her iki çeşit de 4 x 2 m dikim mesafesinde, toplam 1250 ağaç ha^{-1}'a eşit olacak şekilde dikilmiştir. Elde edilen sonuçlar, "Koroneiki" çeşidinin "Picual" çeşidinden daha erkenci olduğunu ve ekimden 2 yıl sonra meyve vermeye başladığını göstermiştir. Anca, 'Koroneiki'ye göre daha geç verime yatan 'Picual' çeşidi, 5 yıl sonundaki kümülatif verimler incelendiği zaman 'Koroneiki'yi yakaladığı görülmüştür. Sonuçlar doğrultusunda 'Koroneiki'nin yağ veriminin (yaş meyve ağırlığının %'si) % 21.02'den % 22.67'ye; 'Picual'ın yağ veriminin ise % 18.47'den % 20.13'e kadar değiştiği belirlenmiştir. 'Picual' çeşidinin 'Koroneiki' daha düşük bir yağ verimi (yaş meyve ağırlığının %'si) olmasına karşın, ağaç başına yağ veriminin (kg) daha yüksek olduğu belirlenmiştir.

Anahtar Sözcükler:
Zeytin ağacı peformansı
Kümülatif zeytin verimi
Meyve ağırlığı
Serbest yağ asidi
Peroksit değeri

1. Introduction

Olive tree (*Olea europea* L.) is reported to be a drought tolerant species (Orgaz and Fereres, 1997) which is an important tree in the habitats of Cyprus as in many other Mediterranean countries (Meikle 1977; Egoumenidou, 2005). Olive oil is reported to be very beneficial for human health while it helps human body to fight against cardiovascular disease (Serra-Majem et al., 2003). Production and consumption of olives (mainly as olive oil) is continuously increasing all over the world, due to its scientifically noted health benefits (Menendez et al., 2006; Ocakoglu et al., 2009). Olive production in Cyprus is mainly focused on wild varieties with low yield and quality, while at the same time, olive plantations are generally found on hills with high distance among the trees. Yield and quality of olive and olive oil are significantly influenced by olive cultivar (Tura et al., 2007) climate and geographical production area (Cerretaini et al., 2006; Temine et al, 2006), and production system (Lozano-Sanchez et al., 2010).

Many studies suggested that some wild or clonal cultivars are suitable for high density plantations, and

high density plantations improve fruit yield per area (Tous et al., 2010; Farinelli et al., 2012; Abenoza et al., 2014). Abenoza et al. (2014) reported that the choice of correct variety is utmost important in high density planting systems to reach high yield and ensure mechanical harvesting. Traditional varieties of Cyprus are known to be un-suitable for high density planting system (Anestiadou et al., 2017), where few or no studies were carried about the adaptation and suitability of other clonal, newly developed cultivars in Northern Cyprus. The olive cultivar cv. Koroneiki is reported to be suitable for high density planting systems (Allalout et al., 2011) but not tested in Northern Cyprus before (Allalout et al., 2011). This research aimed to study the olive and oil yield and quality performance of 'Koroneiki' and 'Picual' grown in high density planting systems in Northern Cyprus.

2. Materials and Methods

This research was conducted in an experimental orchard, which was established in May 2012 at the Research and Application Farm of the European University of Lefke, near Güzelyurt city (35°11'07.05" N, 32°58'27.92" E, altitude 45 m a.s.l.). Seedlings of *Olea europea* L. cv. 'Picual', and cv. 'Koroneiki' were planted with a pattern of 4 x 2 m (1250 trees ha^{-1}). The researches had been continued for 5 consecutive crop years from 2013 (2^{nd} growing year) to 2017 (6^{th} growing year). Average minimum temperature of the region is around 7 °C (measured in January) where the average highest temperature reaches up to 35 °C in August. The mean rainfall of the region during the 5 years of study was 346.74 mm. The soil of the research area is clay loam with about 2.5% organic matter content. Picual is known as the most abundant variety in the world. The name of the variety is coming from the fruit's pointed tip shape. The oil quality is known as good and is prized for its high stability (resistance to oxidation) and this characteristic gives it great resistance to high temperatures (Anonym, 2018a). The Koroneiki tree was reported to grow in Greece for more than 3,000 years. The fruits of this variety are very small, but they contain high oil content which include very high levels of poly-phenols. In Greece, the Koroneiki is considered as the 'queen of olives' (Anonym, 2018b).

Completely randomized block design was used for the experiments and 3 replications (each with 30 trees) were assigned for each treatment. Trees were trained as a single trunk training system. The orchard was irrigated through a drip irrigation system according to the needs of the plants. Regular control of pests and diseases performed. One to two pesticide applications performed for controlling olive fruit fly (*Bractocera oleae*). Harvesting of 'Picual' was performed in December and of 'Koroneiki' was performed in January, depending on the maturity index and season. Olive skin and pulp colours were used as a guideline for the maturity index. Fruits of the 24 out of 30 trees of each replication were used for yield analyses (kg $tree^{-1}$) which were hand-picked by professional workers. Three trees from each side of the replications were not used for further analysis to prevent any side-effects. Five trees out of 24 were selected from each replication and 10 fruits were sampled from each tree to assess their mean weight (g), polar diameter (mm) and equatorial diameter (mm) in 2016 and 2017. Olive oil was extracted with an industrial olive mill. The malaxation temperature was 28 °C for 30 min. After malaxation, oil was separated with a vertical centrifuge and left to decant. Oil yield per tree (kg) and oil (% of fruit weight) were then calculated. Oil samples were kept in dark bottles at 4 °C till further chemical analysis (Bourazanis et al., 2016). International Organization for Standardization (ISO) 660 analytical method was used for the measurement of free fatty acid (% oleic acid) and peroxide value (mEq O_2 kg^{-1}) was assessed by titration of samples with sodium thiosulfate according to the European Union standard methods (Commission Regulation EEC/2568/91).

Data of the experiments was subjected to independent samples t-test (5% and 1%) to determine any significant differences among the cultivars, and one-way analysis of variance was performed to assess the statistical significance among the years. SPSS 22.0 was used for the data analysis.

3. Results and Discussions

According to the results, the 'Koroneiki' cultivar was found to be more precocious than 'Picual' by boring fruits in the second year (Table 1.). First yield from the 'Picual' cultivar was obtained in 2016 (5^{th} year after planting). Both olive and oil yield of the cultivars showed significant differences in all years. The yield of 'Koroneiki' cultivar showed considerable increase from second year to third year, and then it stayed similar. The highest yield from 'Koroneiki' cultivar was measured in 4^{th} year with 7.96 kg $tree^{-1}$ and is followed by 6^{th} year with a yield of 7.69 kg $tree^{-1}$. The 'Picual' cultivar was found to be late in fruit bearing, but its yield was found to be significantly higher than the 'Koroneiki', where the cumulative yield of 'Picual' reached 'Koroneiki' in two years, and no significant difference was obtained for cumulative olive yield (Figure 1.). According to the results, it might be suggested that both cultivars have no 'on' and 'off' seasons. The oil results of 'Picual' and 'Koroneiki' varied from 18.47 % (first harvest of 'Picual' in 5^{th} year) to 22.67 % (final harvest of 'Koroneiki' in 6^{th} year) (Table 1.). Olive oil yield of the two cultivars showed significant differences. 'Koroneiki' cultivar was found to have higher oil yield than 'Picual' in all years. Olive oil yield (% of fruit weight) is an important parameter, but oil yield per tree (kg) is more important for olive growers. The oil per tree findings of two cultivars varied from 0.09 kg (first harvest of 'Koroneiki' in 2^{nd} year) to 3.46 kg (final harvest of 'Picual' in 6^{th} year) (Table 2.). Cultivars

showed significant differences for olive oil per tree (kg) in all years. Oil yield per tree (kg) of 'Picual' cultivar in 6th year after planting is around double of the 'Koroneiki' cultivar. Cumulative oil yield (kg ha^{-1}) of 'Koroneiki' in 5 consecutive years is found to be higher than the 'Picual' (Figure 1.). However, results may suggest that cumulative oil yield of 'Picual' cultivar would pass 'Koroneiki' in two more consecutive years. Olive and oil yield results of 'Koroneiki' are in conjunction with the results of Barranco (2010) and the results of 'Picual' are in agreement with the notes of Hagagg et al. (2013).

Table 1. Olive yield (kg $tree^{-1}$) and olive oil yield (% of fruit weight) of 'Picual' and 'Koroneiki' cultivars 5 successive growing seasons

Cultivars	2013 – 2nd	2014 – 3rd	2015 – 4th	2016 – 5th	2017 – 6th
	Total Yield (kg $tree^{-1}$)				
Picual	0.00	0.00	0.00	12.15 ** b	17.18 ** a
Koroneiki	0.43 c	6.77 b	7.96 a	6.92 ** b	7.69 ** a
	Oil (% of fruit weight)				
Picual	0.00	0.00	0.00	18.47 ** b	20.13 ** a
Koroneiki	21.12 c	21.02 c	21.72 b	22.00 ** b	22.67 ** a

*Values followed by the ** within the same column are significantly different at 1% level (independent samples t-test); and values followed by the same letter or letters within the same row are not significantly different at 5% level (Tukey's HSD multiple range test

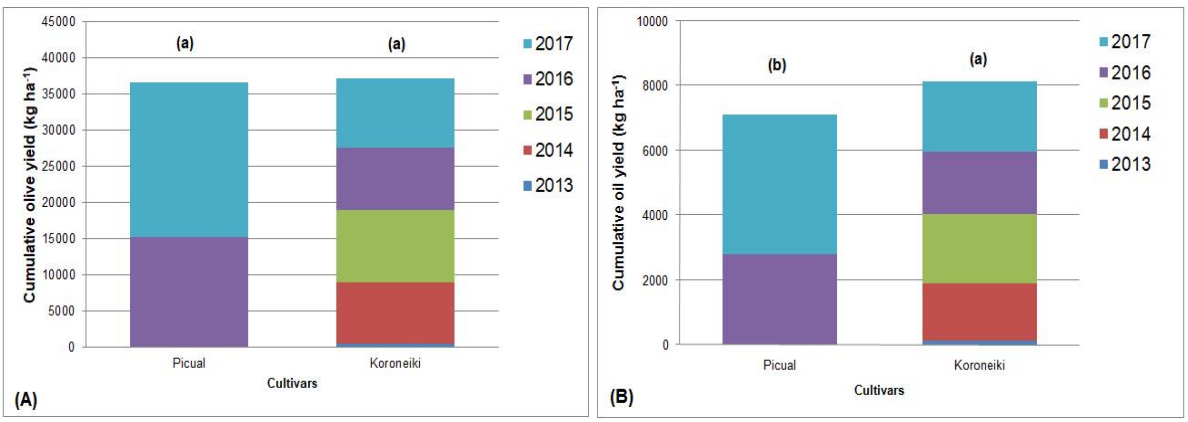

Figure 1. Cumulative yield (kg ha^{-1}), for olive (A) and olive oil (B) of 'Picual' and 'Koroneiki' cultivars after 6 years from plantation. Values followed by the same letter or letters are not significantly different at 1% level (independent samples t-test)

Table 2. Olive oil per tree (kg), free fatty acid (% oleic acid) and peroxide value (mEq O_2 kg^{-1}) of 'Picual' and Koroneiki' cultivars 5 successive growing seasons

Cultivars	2013 – 2nd	2014 – 3rd	2015 – 4th	2016 – 5th	2017 – 6th
	Oil per tree (kg)				
Picual	0.00	0.00	0.00	2.24 ** b	3.46 ** a
Koroneiki	0.09c	1.42b	1.73a	1.52 ** b	1.74 ** a
	Free Fatty Acidity (% oleic acid)				
Picual	0.00	0.00	0.00	0.49 ** a	0.40 ns b
Koroneiki	0.52 a	0.50 a	0.49 a	0.39 ** b	0.38 ns b
	Peroxide value (mEq O_2 kg^{-1})				
Picual	0.00	0.00	0.00	12.83 ** a	11.23 ** b
Koroneiki	6.19 ab	6.07 c	6.15 b	6.21 ** a	6.23 ** a

*Values of same parameter followed by the ** within the same column are significantly different at 1% level (independent samples t-test) and ns represents no significant differences. Values followed by the same letter or letters within the same row are not significantly different at 5% level (Tukey's HSD multiple range test)

The IOC (International Olive Council) standard for free fatty acid (% oleic acid) is reported to be less than 0.8 % and for peroxide value (PV) is smaller than 20 mEq O_2 kg^{-1} oil (Mailer and Beckingham, 2006; EUC, 1991, 2011). FAA values of both cultivars were found to be lower than the upper limit determined by IOC for extra virgin olive oil (Table 2.). Free fatty acid (FAA) is on the other hand is a good indicator for the longer storage of the olive oil, where lower the FAA, higher the storage duration. FAA and PV contents of the two studied cultivars showed slight fluctuations year-to-year. FAA content of the cultivars showed slight decrease since the trees getting older. In the final year, no significant difference was measured among the cultivars for FAA. Previous studies suggested that oil acidity might be variable depending on the age of the trees and climatic conditions (Dag et al., 2011; Rodrigues et al., 2018). In present study, FAA of 'Picual' cultivar was found to be lower; and PV higher than the results of Reboredo-Rodríguez (2015). However, PV of both 'Picual' and 'Koroneiki', in all seasons, were found to be lower than the IOC limit (20 mEq O_2 kg^{-1}). The results are in accordance with the findings of Bourazanis et al. (2016) for Koroneiki. The PV values of 'Picual' cultivars were lower than the IOC limit but higher than 10 mEq O_2 kg^{-1}, in which Mailer and Beckingham (2006) reported that PV values higher than 10 may be considered not good for long shelf life.

Significant differences determined for individual fruit weight between 'Picual' and 'Koroneiki' cultivars (Table 3.). As expected, the fruit weight of 'Picual' was found to be higher than 'Koroneiki'. The polar and equatorial diameter of 'Koroneiki' was also significantly lower than the 'Picual' cultivar (Figure 2.).

Figure 2. Fruits of the 'Picual' and 'Koroneiki' cultivars

Table 3. Mean fruit weight (g), polar fruit diameter (mm) and equatorial fruit diameter (mm) of 'Picual' and 'Koroneiki' cultivars for 2016 and 2017 growing seasons

Varieties and years/ Parameters	Picual			Koroneiki		
	2016	2017	Average	2016	2017	Average
Mean fruit weight (g)	5.16 $^{**\ ns}$	4.91 $^{**\ ns}$	5.04	0.70 $^{**\ ¥}$	0.45 $^{**\ ¥}$	0.58
Polar diameter (mm)	25.02 $^{**\ ns}$	24.77 $^{**\ ns}$	24.90	14.16 $^{**\ ¥}$	12.99 $^{**\ ¥}$	13.58
Equatorial diameter (mm)	18.45 $^{**\ ns}$	18.14 $^{**\ ns}$	18.30	9.73 $^{**\ ¥}$	9.10 $^{**\ ¥}$	9.42

*The first symbol following the values, the ** within the same row represents significant differences among the cultivars in same years; and the second symbol $^{¥}$ represents significant differences among the years; where ^{ns} represents no significant differences for all, at 1% level (independent samples t-test).

4. Conclusions

Current research is the first study reporting the olive and oil yield and quality of 'Picual' and 'Koroneiki' cultivars in high density planting system in Northern Cyprus. It is also important to test their olive and oil yield and quality under normal planting systems. Present study indicates that both cultivars are suitable for high density planting systems in Northern Cyprus having Mediterranean climate. 'Koroneiki' cultivar is found to be a promising cultivar in Northern Cyprus, while olive yield had substantial increase in time. However, 'Picual' cultivar with bigger fruits is noted to have higher cumulative yield than 'Koroneiki' cultivar. It should be kept in mind that yield data for 'Picual' cultivar was collected in only two years; thus further studies are necessary for reliable conclusions. Results also showed that oil yield (% of fruit weight) is not a good indicator for the economic analysis of the cultivars, while oil yield per tree (kg) might be *vice versa* with the oil yield (% of fruit weight).

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