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Effects of zeolite applications on the mineral elements and fatty acid composition of different olive cultivars *

Zeolit uygulamalarının farklı zeytin çeşitlerinin bitki besin elementleri ve yağ asidi kompozisyonu üzerine etkisi

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ABSTRACT

Objective: The objective of this study was to determine effect of different zeolite doses on plant macro nutrient concentrations, fatty acid contents and fruit weights of Gemlik and Manzanillo olive cultivars.

Material and Methods: The experiment was designed as randomized plots with three replications in Gemlik and Manzanillo olive cultivars at 7x7 m spacing. Increasing doses of zeolite (0, 500, 1000, 2000 and 3000 g tree^{-1}) were applied.

Results: In Gemlik and Manzanillo cultivars, the levels of N, P and Ca elements in the leaves were found to be at sufficient levels. Also K concentration in Z3 and Z4 applicatins, and Mg concentrations in Z2, Z3 and Z4 applications were found to be sufficient.

Conclusion: In general, fatty acid levels varied according to zeolite applications; the order followed: oleic acid > palmitic acid > linoleic acid > stearic acid. Gemlik and Manzanillo were included in the high class category according to their fruit weight. The Z4 dose (3000 g tree^{-1}) was more effective in applications.

Keywords: Fatty acid, oleic acid, olive, plant nutrient, zeolite

ÖZ

Amaç: Bu araştırma, farklı zeolit dozlarının Gemlik ve Manzanilla zeytin çeşitlerinde makro bitki besin elementi konsantrasyonları, yağ asidi içerikleri ile meyve ağırlıkları üzerindeki etkisini incelemek için yapılmıştır.

Materyal ve Yöntem: Deneme Gemlik ve Manzanilla zeytin çeşitlerinde 7x7 m aralıklarda ve tesadüf parselleri deneme desenine göre üç tekerrürlü olarak kurulmuştur. Artan dozlarda zeolit (0, 500, 1000, 2000 ve 3000 g ağaç$^{-1}$) uygulanmıştır.

Araştırma Bulguları: Gemlik ve Manzalina çeşitlerinde yapraklardaki N, P ve Ca elementlerinin seviyeleri yeterli düzeyde bulunmuştur. Ayrıca, K konsantrasyonu Z3 ve Z4 uygulamalarında, Mg konsantrasyonu ise Z2, Z3 ve Z4 uygulamalarında yeterli bulunmuştur.

Sonuç: Genel olarak zeolit uygulamalarına göre yağ asidi farklılık göstermiş olup; oleik asit > palmitik asit > linoleik asit > stearik asit sırasını izlemiştir. Gemlik ve Manzanillo meyve ağırlıklarına göre yüksek sınıf kategorisi içerisinde yer almıştır. Uygulamalar içerisinde Z4 dozu (3000 g tree^{-1}) daha etkin olmuştur..

Anahtar sözcükler: Yağ asidi, oleik asit, zeytin, bitki besin elementi, zeolit

INTRODUCTION

Zeolite has the potency to be used within the agricultural intensification processes and agroindustry. It is a chemical compound mainly composed by alumina-silicate with oxygen bonded and repeatedly connected each other to make a channel and micropore cage that could be filled by metal like sodium, potassium, calcium and magnesium as compensation of electron excess from aluminium. In general, zeolite could be divided into two parts such as natural and synthetic zeolite. Application of natural zeolite has been widely known for its agricultural purposes like soil improvements, fertilizing agent and medium for planting (Cerri et al., 2016). Zeolites have three properties for agricultural purposes: 1- high water holding capacity in free channels in soil, 2-high cation exchange capacity and 3-high adsorption capacity (Hedström, 2001). It was stated that the application of volcanic zeolite tuff in olive trees (*Olea europaea* L.) increased shoot length, plant height, plant weight, number of branches, number of leaves, stem diameter and shoot diameter, leaf relative water content and leaf water potential (Al-Tabbal et al., 2020), zeolite application (5 t ha^{-1}) increased soil moisture, fruit fatty acid composition and oil quality (Martins et al., 2022), and zeolites (1500 kg ha^{-1}) has been reported to provide significant yield increases of 31.6% and 35.5%, respectively, in olive trees (Martins et al., 2023). Zeolite is generally alkaline reaction and when used in combination with fertilizers it can help buffer soil pH levels, thus reducing the need for lime application (Polat et al., 2004). Zeolite applications to soils can act as slow release fertilizers and increase water holding capacity, improving water and nutrient use efficiency (Nakhli et al., 2017). Natural crystalline structure and Clinoptilolite was found to be the most common natural zeolite mineral (Kurniawan et al., 2018). Clinoptilolite-rich tuff as a soil conditioner significantly increases the yields of wheat (13-15%), eggplant (19-55%), apples (13-38%) and carrots (63%) with the use of zeolite (Mazur et al., 1984). On the other hand, synthetic zeolite usually used as a catalyst in the industrial commercial application such as refinery factory, petrochemical plant and adsorption agent for gas treatment industry (Primo et al., 2014). Because of physical and chemical properties, clinoptilolite [$(Na_3.K_3)$ $(Al_6Si_{30}O_{72}).24H_2O$] is used as a slow-release fertilizer and commonly used as growth medium (Mumpton, 1999). Zeolite is highly economical in terms of reducing fertilizer use and preventing environmental pollution by reducing the leaching of the elements (Gül et al., 2005). Olive (*Olea europaea* L.) is a plant commonly grown in the Mediterranean region. Its fruit is used to produce oil, table olives and other by-products. The main nutrient of olive fruit is oil, predominantly monounsaturated fatty acids. Olives are also rich in carbohydrates, vitamins and minerals (Guo et al., 2018). The fruit of the Gemlik olive variety is black in color, for table use, and also has a high oil content of up to 29%. The Gemlik tree is generally of medium size, with a rounded crown and medium vigor (Anonymous, 2000). Manzanillo, in other words, Manzanillo cultivar is quite widespread in Spain and it is known to be spread from Spain to entire world. Because of its superior taste, availability for cultivation and processing techniques, Manzanillo is the most widely used green table olive. Totally because of the aroma of Manzanillo, Spain is the largest green olive trader country of the world (Lopez-Lopez et al., 2015). The most abundant fatty acids were stated as oleic acid (C18:1), linoleic acid (C18:2) palmitic acid (C16:0) and stearic acid (C18:0), so these fatty acids have been identified. Oil composition and quality vary according to several factors, such as climate conditions, harvest time and agronomic practices (Jimenez-Lopez et al., 2020).

The objective of this study was to determine the effect of different zeolite doses on plant nutrient (nitrogen, phosphorus, potassium, calcium and magnesium) concentrations, fatty acid (linoleic acid, oleic acid, palmitic acid and stearic acid) contents and fruit weights of Gemlik and Manzanillo olive cultivars. Presence of zeolite resources and properties of zeolite in our country seem to be a promising sustainable strategy to implement in olive orchards. The effects of potassium level in the structure of zeolite on olives were tried to be tested.

MATERIALS and METHODS

The study was conducted during two successive years (2011-2012) in the orchards of Ege University Agricultural Faculty Soil Science and Plant Nutrition Department. The olive grove was 10 years old and was established with Gemlik and Manzanillo olive cultivars at 7x7 m spacing. The experiment was designed as randomized plots with three replications with a single tree in each replicate. Zeolite treatments were applied for two years. Some properties of zeolite used in the experiment pH (1:2.5 water extract)=8.19, EC (dS m^{-1}) =0.596, Total nitrogen (N) (%) =0.016, available phosphorus (P)=1.84 mg kg^{-1}, available potassium (K)=10403.3 mg kg^{-1}available calcium (Ca)=3018.4 mg kg^{-1}, available magnesium (Mg)=606.0 mg kg^{-1}, available natrium (Na)=657.6 mg kg^{-1} and particle size (mm) < 4 the properties of the zeolite used in the experiment are as specified. Treatments were applied at 5 different doses (control (Z0); 500 (Z1), 1000 (Z2), 2000 (Z3) and 3000 g zeolite $tree^{-1}$ (Z4); to tree canopy projection at the beginning of February, zeolite application doses were made according to Mumpton (1999). Nitrogen and phosphorus were used at constant doses. Ammonium nitrate NH_4NO_3 (33% N) and Triple Super Phosphate (TSP) (44-46% P_2O_5) were used as N and P source. NH_4NO_3 fertilizer (600 g N $tree^{-1}$) and Triple Super Phosphate (TSP) fertilizers (400 g P_2O_5 $tree^{-1}$) were applied to 15-20 cm deep plow grooves and grooves were closed with a plow. Soil analysis results for experimental olive grove are provided in Table 1.

Table 1. Analysis results of the soils where the olive varieties are grown

Çizelge 1. *Zeytin çeşitlerinin toprak analiz sonuçları*

Properties		Gemlik	Manzanillo
pH		7.40	7.46
Total salt	(%)	0.068	0.079
$CaCO_3$	(%)	23.91	24.62
Sand	(%)	29.2	30.6
Silt	(%)	32.4	29.4
Clay	(%)	38.4	40.0
Texture class		Clay loam	Clay loam
Organic matter	(%)	2.22	2.68
Total N	(%)	0.101	0.112
Available P	(mg kg^{-1})	2.10	1.71
Available K	(mg kg^{-1})	320.6	348.9
Available Ca	(mg kg^{-1})	7130	7288
Available Mg	(mg kg^{-1})	210.2	237.5
Available Na	(mg kg^{-1})	57.6	38.7
Available Fe	(mg kg^{-1})	7.3	9.8
Available Zn	(mg kg^{-1})	2.1	2.5
Available Cu	(mg kg^{-1})	2.6	2.5
Available Mn	(mg kg^{-1})	14.2	16.4

Analyses conducted on leaf samples

The middle leaf pairs on nonbearing shoots were taken as leaf samples. In both years, leaf samples were taken from all sides of the olive trees at the end of November (Jones et al., 1991). Leaf samples were washed through distilled water, dried at 65-70°C and ground to make them ready for analyses. Nitrogen contents were determined according to Kjeldahl method (Bremner, 1965); potassium, phosphorus, calcium and magnesium concentrations were determined from plant extracts obtained through dry-ashing at 500±550°C. Potassium and calcium contents were determined in a flame photometer and Magnesium contents were determined in the Atomic Absorption Spectrophotometer (Kacar & İnal, 2008). Phosphorus content was determined calorimetrically (Lott et al., 1956). Fruit weight was obtained as a result of average fruit weight.

Analyses conducted on olive oil

Harvesting was carried out when the color change of the fruit started in both olive varieties, and the oil production of olive varieties reached the highest level in November (Canözer, 1991). At the harvest season, about 1.5-2.0 kg olive samples were collected from each tree of each treatment of Gemlik and Manzanillo olive cultivars. Fatty acid composition was determined by obtaining oil from fruit samples. The oil of olive fruits was extracted by cold extraction method and stored at 4ºC in dark colored bottles until the olive oil quality analysis was achieved (Kutku & Şen, 2011). Cold methylation method (IUPAC Metod 2.301) approved by International Olive Oil Council (IOOC) was used for olive oil esterification. Oil samples were converted into methyl esters, then fatty acid analyses (oil composition) were conducted in a gas chromatography (Agilent Technologies, 6890N brand) device equipped with 60 m Spelco 2380 brand capillary column (60 m x 0.25 mm i.d., 0.20 µm film thickness). Resultant peaks were identified with the use of fatty acid standards and fractions were determined by calculating peak time and area and results were expressed as percentage (Anonymous 1987).

Statistical analysis

Analysis of variance was used to test differences between treatment means. All statistical analyses were conducted using SPSS statistics 20.0 software, at a probability levels of $p < 0.05$.

RESULTS and DISCUSSION

Leaf macro elements

In Gemlik cultivar, N contents varied between 1.89-2.00% and 1.93-2.05% in the two successive years (Table 2).

Table 2. Effects of treatments on macro plant nutrient contents in leaves of olive varieties

Çizelge 2. *Zeolit uygulamasının zeytin çeşitlerin yaprağın makro bitki besin içeriğine etkisi*

		2011 (%)					2012 (%)				
	T^x	N	P	K	Ca	Mg	N	P	K	Ca	Mg
Gemlik	Z0	1.89±0.06	0.12b±0.02	0.81b±0.01	2.01±0.01	0.16b±0.01	1.93±0.04	0.10b±0.01	0.82b±0.05	2.06±0.08	0.16b±0.02
	Z1	1.91±0.10	0.12b±0.02	0.86ab±0.07	2.05±0.05	0.22ab±0.05	1.95±0.03	0.12b±0.01	0.88b±0.04	2.06±0.08	0.20ab±0.02
	Z2	1.93±0.08	0.15ab±0.05	0.87ab±0.06	2.07±0.09	0.24a±0.03	1.99±0.09	0.17b±0.07	0.88b±0.06	2.09±0.07	0.22a±0.05
	Z3	2.00±0.11	0.23a±0.09	0.94ab±0.03	2.09±0.08	0.22ab±0.01	2.05±0.05	0.26a±0.06	0.94ab±0.04	2.14±0.02	0.21a±0.04
	Z4	1.98±0.07	0.16ab±0.04	1.01a±0.10	2.05±0.06	0.22ab±0.03	2.02±0.07	0.17b±0.02	1.05a±0.11	2.12±0.06	0.22a±0.03
	LSD	ns	0.079*	0.151**	ns	0.070**	ns	0.079*	0.151**	ns	0.052*
Manzanillo	Z0	1.82b±0.02	0.18b±0.02	0.84b±0.02	2.07±0.11	0.20±0.03	1.87b±0.07	0.19b±0.04	0.82b±0.06	2.11±0.10	0.18±0.01
	Z1	1.82b±0.08	0.21ab±0.04	0.84b±0.12	2.06±0.03	0.22±0.06	1.91b±0.08	0.21b±0.02	0.88b±0.07	2.14±0.05	0.21±0.06
	Z2	1.84b±0.08	0.21ab±0.04	0.86b±0.10	2.09±0.17	0.18±0.03	1.99b±0.12	0.22ab±0.03	0.88b±0.05	2.18±0.05	0.19±0.02
	Z3	1.90ab±0.07	0.23ab±0.04	1.04a±0.06	2.19±0.03	0.23±0.01	2.17a±0.04	0.22ab±0.03	0.94ab±0.04	2.13±0.04	0.22±0.03
	Z4	2.02a±0.06	0.26a±0.02	1.10a±0.05	2.16±0.07	0.20±0.04	2.19a±0.03	0.28a±0.04	1.05a±0.02	2.05±0.08	0.20±0.06
	LSD	0.165**	0.054*	0.152**	ns	ns	0.165**	0.073**	0.152**	ns	ns

* p<0.05, ** p<0.01; T^x; Treatments, ns: not significant

In Manzanillo cultivar, N contents varied between 1.87-2.02% in the first year and between 1.87-2.19% in the second year. In Gemlik cultivar, leaf P contents varied between 0.12-0.23% in the first year and between 0.10-0.26% in the second year. In Manzanillo cultivar, P contents varied between 0.18-0.26% in the first year and between 0.19-0.28% in the second year. Effects of zeolite treatments on leaf potassium (K) contents were also found to be significant. In Gemlik cultivar, leaf K contents varied between 0.81-1.01% in the first year and between 0.82-1.05% in the second year. In Manzanillo cultivar, leaf K contents varied between 0.84-1.10% in the first year and between 0.82-1.05% in the second year. Based on zeolite treatments, lead Ca contents of Gemlik cultivar varied between 2.01-2.09% in the first year and between 2.06-2.14% in second year; Ca contents in Manzanillo variety varied 2.06-2.19% in the first year and between 2.05-2.18% in the second year. Effects of zeolite treatments on magnesium contents of Gemlik cultivar were found to be significant. Based on treatments, leaf Mg contents of Gemlik cultivar varied between 0.16-0.24% in the first year and between 0.16-0.22% in the second year; Mg contents of Manzanillo variety varied between 0.18-0.23% in the first year and between 0.18-0.22% in the second year. Zeolite applications did not have a significant effect on the N content of the leaf in the Gemlik olive cultivar and the lowest total N concentration in control (Z0) treatment and the highest total N concentration in Z3 treatment. In Manzanillo olive tree total N concentrations were found to be significant ($p<0.01$). In both years, the highest total N concentration was observed in Z4 treatment. Such differences in N contents of olive leaves were mostly attributed to differences in growing practices cultivars (Fernandez-Escobar et al., 2015). Present findings on N contents were similar with the findings obtained by Irget et al. (2010). N deficiency level for Gemlik and Manzanillo cultivars was reported as 1.2% by Fernandez-Escobar et al. (2009). Present values were higher than this deficiency level, thus present leaves were found to be sufficient in N levels. According to the results obtained also between the sufficiency limits of 1.50-2.50% indicated by Jones et al. (1991).

Effects of zeolite treatments on leaf P contents were found to be ($p<0.05$) significant level. Based on zeolite treatment doses, the highest P content was observed in Z3 (0.23%) treatment of Gemlik cultivar and Z4 (0.26%) treatment of Manzanillo cultivar. In Gemlik cultivar the lowest contents of P with 0.12% were observed in Z0 and Z1 treatments and in Manzanillo olive tree P concentration was determined in 0.18% application of Z0. Present findings on leaf P contents were similar with the findings of Fernandez-Escobar et al. (2015). Present values also within the limit values of 0.10-0.30% indicated by Jones et al. (1991), thus indicated that there were not any problems in terms of P nutrition. In general, leaf K contents increased with increasing zeolite doses. Potassium concentration was found to be statistically significant ($p<0.01$) difference according to the applications. However, these differences do not appear to be a standard increase among all applications. The highest K contents were observed in Z4 treatments of both cultivars. K concentrations below 0.4% were considered as serious deficit and above 0.8% were considered as sufficient (Fernández-Escobar, 2007). Considering the sufficiency levels of 0.90-1.20% indicated by Jones et al. (1991), present values revealed that deficient except for doses Z3 and Z4 sufficient K nutrition. Such sufficient levels were attributed to inherent K content of zeolite can be used which hold nutrients in the root zone for plants to use when required which leads to more efficient use of N and K fertilizers (Aghaalikhani et al., 2012). Zeolites decrease application rate of N and K fertilizers, as they themselves are carriers of N and K fertilizers thereby increasing efficacy (Polat et al., 2004). Zeolite application effects of leaf Ca contents were found to be insignificant. In Gemlik cultivar, the highest Ca content was observed in Z3 treatment. In Manzanillo cultivar, the highest Ca content was observed in Z3 application in the first year and in Z2 treatment in the second year. Present findings on leaf Ca contents were similar with the values of Soyergin (1993), but different from the values obtained by Özel (2019). Present values were within the sufficiency limits of 1.00-2.00% indicated by Jones et al. (1991). Gemlik cultivar the highest Mg concentration was determined in the first year Z2 (0.24%), in the following year Z2 and Z4 (0.22%) application and in the manzanillo variety in the first yearZ3 (0.23%) and in the second year Z3 (0.22%) application. The lowest Mg concentration was determined in the Gemlik variety in Z0 (0.16%) application in both years and in the manzanillo variety in the Z2 (0.22%) application in the first year and in the Z0 (0.18%) application in the second year, respectively. Present findings on Mg contents were similar with the values found by Soyergin (1993), but different from the values by Toplu (2000). Leaf Mg contents of Gemlik and Manzanillo olive cultivars were mostly within the sufficiency levels of 0.20-0.60% indicated by Jones et al. (1991), but some samples were not found to be sufficient (Z0) based on these values.

Contents of fatty acids

Palmitic acid contents of Gemlik cultivar varied between 13.13-14.28% in the first year and between 13.86-14.90% in the second year; palmitic acid contents of Manzanillo cultivar varied between 16.05-17.50% in the first year and between 16.60-18.58% in the second year. Stearic acid contents of Gemlik cultivar varied between 3.06-4.80% in the first year and between 2.83-3.43% in the second year; stearic acid contents of Manzanillo cultivar varied between 2.37-2.52% in the first year and between 2.36-3.58% in the second year. Oleic acid contents of Gemlik cultivar varied between 71.84-72.47% in the first year and between 72.02-73.84% in the second year; oleic acid contents of Manzanillo cultivar varied between 63.53-68.16% in the first year and between 66.11-70.14% in the second year. Zeolite treatments had significant effects on palmitic acid contents of Manzanillo cultivar. In Gemlik cultivar, linoleic acid contents varied between 6.68-7.75% in the first year and between 7.20-9.18% in the second year. In Manzanillo cultivar, linoleic acid contents varied between 10.25-12.08% in the first year and between 12.30-13.56% in the second year (Table 3).

Table 3. Effects of zeolite application on fatty acid compositions of olive varieties

Çizelge 3. *Zeolit uygulamasının zeytin çeşitlerinin yağ asidi kompozisyonuna etkisi*

		2011 (%)				2012 (%)			
	T^x	Palmitic acid (C16:0)	Stearic acid (C18:0)	Oleic acid (C18:1)	Linoleic acid (C18:2)	Palmitic acid (C16:0)	Stearic acid (C18:0)	Oleic acid (C18:1)	Linoleic acid (C18:2)
Gemlik	Z0	13.86±1.02	3.17b±1.00	71.97±1.00	6.88±0.97	13.86±0.58	3.01±0.58	72.02±0.99	7.27b±1.00
	Z1	13.13±1.00	3.64ab±1.04	72.47±1.98	6.68±1.06	14.05±0.73	3.18±0.64	72.83±1.03	7.20b±0.98
	Z2	13.91±1.02	3.28b±0.98	71.84±1.04	7.23±1.03	13.94±0.78	3.01±0.38	72.96±0.98	8.16ab±1.04
	Z3	14.28±0.98	4.80a±0.14	72.07±2.02	6.93±0.97	14.39±1.01	2.83±0.72	73.84±1.04	8.45ab±1.05
	Z4	13.73±1.01	3.06b±1.00	72.06±1.00	7.75±1.05	14.90±0.08	3.43±0.47	72.61±1.01	9.18a±0.99
	LSD	ns	1.278*	ns	ns	ns	ns	ns	1.729*
Manzanillo	Z0	16.83ab±0.97	2.42±0.60	66.02ab±5.02	12.08a±1.02	16.60b±0.56	2.36±0.48	66.11±1.03	12.30±1.05
	Z1	16.05b±1.00	2.49±1.02	67.26ab±5.02	11.02ab±1.01	17.57ab±0.60	3.13±0.18	67.72±0.98	12.66±0.98
	Z2	16.11b±1.02	2.39±1.04	68.16a±1.96	10.32b±1.02	17.16ab±0.60	3.08±0.05	70.14±0.95	13.56±1.01
	Z3	17.32ab±0.98	2.37±1.00	66.83ab±0.98	10.25b±0.95	18.50a±0.49	3.58±0.64	69.02±1.00	13.33±1.06
	Z4	17.50a±1.00	3.52±1.02	63.53b±3.03	12.05a±0.95	18.58a±0.50	3.45±0.59	66.31±1.12	13.13±1.03
	LSD	1.369*	ns	4.495*	1.717*	1.867**	ns	ns	ns

* $p<0.05$, ** $p<0.01$; T^x ;Treatments, ns: not significant

Zeolite treatments had significant effects on oleic acid contents of Manzanillo cultivar. Major fatty acids of present olive oils were identified respectively palmitic (C18:0), stearic acid (C18:0), oleic (C18:1) and linoleic (C18:2) and (Monfreda et al., 2012), respectively. Gemlik cultivar the highest linoleic acid contents was determined in the first year Z4 (7.75%), in the following year Z4 (9.18%) application and in the manzanillo variety in the first year Z0 (12.08%) and in the second year Z2 (13.56%) application. The smallest content was determined in the Gemlik variety in Z1 (6.68%) in the first year and second year Z1 (7.20%) and in the manzanillo variety in the Z3 (10.25%) application in the first year and in the Z0 (12.30%) application in the second year respectively. Manzanillo cultivar had higher linoleic acid content than Gemlik cultivar. There was no statistical difference between the linoleic acid values of Gemlik cultivar in 2011 and Manzanilla cultivar in 2012. Linoleic acid value in Manzanilla cultivar in 2011 was statistically the same in Z0 and Z4 applications. Gemlik cultivar the highest oleic acid contents was determined in the first year Z1 (72.47%), in the following year Z3 (73.84%) application and in the manzanillo variety in the first year Z1 (67.26%) and in the second year Z2 (70.14%) application. The highest oleic acid content was observed in

Z3 treatment of Gemlik cultivar with 73.84%. Only in 2011, oleic acid values were found to be statistically significant among applications in Manzanilla cultivar. The highest oleic acid value was obtained by the application of Z2 dose. Douzane et al. (2012) emphasized that varietal difference was an effective criterion on oleic acid and linoleic acid (Hernandez et al., 2011). The highest palmitic acid contents were determined in Gemlik cultivar with Z3 (14.28%) application in the first year and Z4 (14.90%) application in the second year, while in manzanillo variety was calculated in Z4 (17.20%) application in the first year and Z4 (18.58%) application in the second year, respectively. The smallest content was determined in the Gemlik variety in Z1 (13.13%) in the first year and second year Z0 (13.86%) and in the manzanillo variety in the Z1 (16.05%) application in the first year and in the Z0 (16.60%) application in the second year respectively. Manzanillo cultivar had higher palmitic acid content than Gemlik cultivar. The highest value and smallest stearic acid contents were determined in Gemlik variety in Z3 (4.80%) application in the first year and the lowest value in Z4 (3.06%) application and in the second year in Z4 (3.43%) applications and the lowest value in Z3 (2.83%) application. Manzanillo variety were determining the highest value fist year Z4 (3.52%) application and Z3 (3.58%) second year and the smallest values were determined in Z3 (2.37%) and Z0 (2.36%) applications in respectively. Fatty acid is ordered from as oleic acid (C18:1)> palmitic acid (C16:0)> linoleic acid (C18:2)>and Stearic acid (C16:0) respectively. Present values of Gemlik and Manzanillo oil cultivars were within the values specified by The International Olive Council (2022) for for palmitic acid (7.00-20.00%), stearic acid (0.50-5.00%), oleic acid (55.00-85.00%) and linoleic acid (2.50-21.00%). Oleic acid was the highest concentration and this acid was more dominant in Gemlik oils (Kesen et al., 2017). As it was indicated by Leon et al. (2004), fatty acids of present cultivars were ordered as oleic acid > palmitic acid > linoleic acid > stearic acid. Oleic acid was the major fatty acid in both cultivars Menz & Vriesekoop 2010 (Gordal Sevillana Olives (*Olea europaea* L., cv. Gordal Sevillana), Şen & Esen Koşaran, 2021 (*Olea europea* L. cv. Ayvalık Yağlık), Oleic acid (62.77-63.86%)>palmitic acid (15.90-16.51%) > linoleic acid (12.72-14.15%)>stearic acid (4.17-4.34%) and it is observed that they are similar to the values stated by Didin et al. 2021 (natural olive oil). Present fatty acid contents of Gemlik cultivar were similar with the values as recommended by Yorulmaz et al. (2010) for palmitic acid (13.33%), stearic acid (2.59%), oleic acid (72.34%) and linoleic acid (8.57%), but different from the values of Tanılgan et al. (2007) for palmitic acid (8.1%), stearic acid (5.6%), oleic acid (81.1%) and linoleic acid (4.9%). Such differences were mainly attributed to the differences in climate conditions, cultural practices and harvest dates (Motilva et al., 2000). Sweeney (2005) reported major fatty acids of Manzanillo cultivar as palmitic acid (13.24%), stearic acid (2.92%), oleic acid (72.97%) and linoleic acid (7.39%); Galeano Diaz et al. (2005) reported major fatty acids of Manzanillo olive cultivar as palmitic acid (12.04%), stearic acid (1.98%), oleic acid (79.03%) and linoleic acid (4.49%). Torres & Maestri (2006) reported major fatty acids of Manzanillo olives grown in Argentina as palmitic acid (15.2-16.9%), stearic acid (1.43%), oleic acid (72.2%) and linoleic acid (8.34%). Present fatty acid contents were somehow different from these literature findings. Nutritionally, the ratio of oleic/palmitic acid (C18:1/C16:0) is important (Pacheco et al., 2006). Currently, oleic/palmitic acid ratio <5 is recommended (Simopoulos, 2008). In Manzanillo olive variety the average ratios were close to this level (about 3.56 and 4.23 respectively), but Gemlik olive variety This ratio was higher than 5 in Gemlik variety (about 4.87 and 5.51 respectively), and other factors that influence the physical and chemical composition of the fruit (Ghanbari et al., 2012). Olive oil composition influenced by several factors like cultivar, environment, agronomic practices processing and storage (Guerfel et al., 2012), geographic area, maturity index, climatic conditions (rainfall, temperature, humidity) and agricultural practices (Borges et al., 2017).

The fruit weight in Gemlik variety olive were determined to be 4.23-4.60 g in the 1st year and 4.29-4.58 g in the 2nd year and Manzanillo variety first year 4.41-4.76 g and in the second year 4.44-4.85 g. In both varieties, the lowest fruit weight was obtained from the control (Z0) application, and the highest fruit weight was obtained from the zeolite (Z4) application (Table 4). Fruit weight levels, measured were below according to the (5.15-7.65 g) Ozdemir et al. (2018). The following characteristics were evaluated and classified according to Methamem et al. (2015), for fruit weight: low (< 2 g), medium (2 to 4 g), high (4 to 6 g) and very high (> 6 g). Gemlik and Manzanillo Fruits is in high group

Table 4. Effects of zeolite applications on the fruit weights of olive varieties

Çizelge 4. *Zeolit uygulamasının zeytin çeşitlerin meyve ağırlıklarına etkisi*

T^x	Gemlik (g)		Manzanillo (g)	
	2011	2012	2011	2012
Z0	4.23±0.24	4.29±0.36	4.41±0.11	4.44±0.23
Z1	4.26±0.51	4.32±0.43	4.45±0.32	4.55±0.26
Z2	4.29±0.22	4.31±0.55	4.58±0.43	4.67±0.41
Z3	4.52±0.25	4.40±0.20	4.71±0.48	4.80±0.62
Z4	4.60±0.34	4.58±0.26	4.76±0.51	4.85±0.43
LSD	ns	ns	ns	ns

ns: not significant, ^{x} Treatments

CONCLUSIONS

Zeolites have the ability to retain nutrients in the topsoil. Fatty acid contents differed according to zeolite applications and are listed as; oleic acid > palmitic acid > linoleic acid > stearic acid. The use of zeolite in agricultural production has increased. Depending on the soil, climate and growing conditions, the application of zeolite together with chemical fertilizers may have a more beneficial effect on the soil and plant. Due to its slow release fertilizer feature, the applications to be made for the effect of zeolite should be done for many years and it will be more beneficial to apply it on different plants. The dose of zeolite Z4 (3000 g tree^{-1}) application is recommended according to the fruit weight values of olive cultivars.

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