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Research Article

Influence of Irrigation, Variety and Collection Time on Mineral Contents of Olive Leaves

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ABSTRACT

The objective of this study was to evaluate the effect of factors such as irrigation, variety and collection time on mineral contents of olive leaves. The highest Ca (31115.73 mg/kg), K (8398.34 mg/kg) and S (1679.05 mg/kg) contents were determined in leaves of Gemlik variety collected in irrigated orchard. Olive leaves of Ayvalık variety grown in irrigated orchard contained the maximum levels of Mg (3394.94 mg/kg) and P (949.13 mg/kg). The P, K and Mg amounts of olive leaves, in general, showed an increase with irrigation treatment. Generally, a regular increase or decrease did not observe in levels of macro elements of olive leaves based on collection time. Concerning the micro element contents of leaves, the highest Na contents were found in Ayvalık (241.11 mg/kg) and Yağlık (237.65 mg/kg) varieties. An increase was obtained in Fe contents of Yağlık olive leaves with irrigation during collection period. The concentrations of both macro and micro elements showed differences depending on the collection time, irrigation process and variety of olive leaves.

Keywords: Olive leaves, variety, irrigaiton, collection time, mineral

Zeytin Yapraklarının Mineral İçerikleri Üzerine Sulama, Çeşit ve Toplama Zamanının Etkisi

ÖZ

Bu çalışmanın amacı, zeytin yapraklarının mineral içerikleri üzerine sulama, çeşit ve toplama zamanı gibi faktörlerin etkisinin değerlendirilmesidir. En yüksek Ca (31115.73 mg/kg), K (8398.34 mg/kg) ve S (1679.05 mg/kg) içerikleri sulanan bahçeden toplanan Gemlik çeşidinin yapraklarında belirlenmiştir. Sulanan bahçede yetişen Ayvalık çeşidinin yaprakları maksimum seviyede Mg (3394.94 mg/kg) ve P (949.13 mg/kg) içermektedir. Zeytin yapraklarının P, K ve Mg miktarları genel olarak sulama uygulaması ile artış göstermiştir. Genel olarak, zeytin yapraklarının makro element seviyelerinde toplama süresine bağlı olarak düzenli bir artış veya azalma gözlenmemiştir. Yaprakların mikro element içerikleri ile ilgili olarak, en yüksek Na içeriği Ayvalık (241.11 mg/kg) ve Yağlık (237.65 mg/kg) çeşitlerinde bulunmuştur. Yağlık çeşidine ait zeytin yapraklarının Fe içeriklerinde toplama periyodu boyunca sulama işlemiyle artış tespit edilmiştir. Hem makro hem de mikro elementlerin konsantrasyonları toplama zamanına, sulama işlemine ve zeytin yaprağı çeşidine bağlı olarak farklılık göstermiştir.

Anahtar kelimeler: Zeytin yaprakları, çeşit, sulama, toplama zamanı, mineral

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Introduction

Olive tree (*Olea europaea* L.) is economically the most significant and one of the oldest cultivated plants (Zohary et al., 2012; Özcan and Matthaus, 2017). Olive leaves, which are known as by-product of olive tree and obtained after pruning of trees and harvesting of olives, are of interest because of their positive effects on health in the recent years (Molina-Alcaide and Yáñez-Ruiz, 2008). Olive leaves are traditionally used as herbal tea for curing certain diseases due to contain several bioactive compounds in high quantities (Özcan and Matthaus, 2017). The interest of both the public and the scientific community to medicinal plants increases day by day, and the use of these plants in modern medicine is becoming widespread because of availability and safeness (Ozyigit et al., 2018). In addition to bioactive properties, olive leaves are a good source of minerals, which have a great importance in human health due to affect biochemical and physiological processes in metabolism (Łozak et al., 2002).

Since olive varieties are affected differently by ecological factors, requirement of varieties for macro- and micronutrients or their effective use of these nutrients may show differences (Dimassi et al., 1999; Jordao et al., 1999; Toplu et al., 2009). However, the metabolism and function of the plant can be damaged depending on excessive mineral deficiency or accumulation (Cetinkaya et al., 2016). The fertilizer and water deficiency lead to decrease of the photosynthetic rate and shoot growth in the plant, hence fruit yield and quality reduce (Bongi and Palliotti, 1994). Moreover, the lack of water in the plant causes nutritional disorders, especially as it limits the displacement and availability of minerals (Grattan and Grieve, 1999; Bartels and Sunkar, 2005; Yousif et al., 2010). The determination of the mineral contents of olive leaves during the cropping cycle is of importance thanks to the following advantages: (1) detecting nutritional status and requirement of fertilizer of tree, (2) evaluating effectiveness of the fertilization programs, (3) detecting toxicities arising from elements (Bedbabis et al., 2016).

There is lack of studies about the effect of irrigation on mineral contents of olive leaves. This study was performed to investigate the influences of irrigation and also variety and harvest time on macro and micro element amounts of olive leaves.

Material and Methods

Collection of olives leaves

Olive leaves belonged to Ayvalık, Çöpaşı, Gemlik and Yağlık varieties grown in irrigated (altitude: 280 m) and arid (altitude: 307 m) orchards in Mersin (Mut-Çortak) location collected from each side of the three trees, and at 20 days intervals between September and December in 2018. Samples were transferred to the laboratory in paper bags and dried at room temperature prior to analyses. The collection times of olive leaves were September 15th, October 6th, October 27th, November 17th, December 8th, and December 29th, respectively.

Climatic conditions

The average monthly humidity, temperature and total monthly rainfall graphs of the location (Mersin- Mut) where the olives leaves were collected in 2018 are shown in Table 1.

Irrigation process

Irrigation was carried out with a drip irrigation system which was applied once a month for a total of 4 hours. Therefore, the total amount of irrigation water was 640 L/month. Irrigation process was applied till October.

Mineral analysis

Olive leaves weighed 0.2 g for each sample were dissolved in microwave device (Cem MARSXpress, USA) under high temperature (210 ºC) and pressure (200 PSI) with 5 ml of HNO_3 and 2 ml of H_2O_2 (30% w/v) and a 40-cell microwave was used to ensure the reliability of the analysis. A blank and a certified reference material (1547a Wheat Flour, 8346 Condition Wheat Flour, 1547 Peach Leaves, NIST) were added to the set. The volumes of the dissolved samples were completed to 20 ml with deionized water and the concentrations of minerals in the samples determined by Inductively coupled plasma optical emission spectrometry (ICP-OES; Varian-Vista Model, France) (Tošic et al., 2015).

Table 1. Climatic conditions of location collected olive leaves

	January	February	March	April	May	June	July	August	September	October	November	December
Rainfall (kg/m^2)	63.60	32.30	48.60	3.30	33.30	43.10	0.00	0.00	0.80	20.50	24.30	84.90
Temperature(◦C)	8.20	11.20	14.80	19.60	23.10	26.10	30.40	30.30	27.30	20.70	14.50	8.70
Humidity (%)	64.40	68.60	56.80	42.40	50.50	51.60	37.10	36.50	35.80	52.50	55.90	71.00

Climatic conditions were obtained from Konya Meteorology Provincial Directorate

Table 2. Mineral contents of olive leaves

	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
P	Rainfed	Ayvalık	633.23 ± 10.53H	701.75 ± 5.12FG	590.35 ± 8.81IJ	717.29 ± 12.64EF	697.30 ± 11.66FG	685.23 ± 9.59G
		Çöpaşı	331.25 ± 8.73T	348.55 ± 12.01T	427.62 ± 3.56S	424.37 ± 8.37S	483.41 ± 9.84OPQR	571.75 ± 9.43JL
		Gemlik	488.27 ± 10.91OPQ	625.61 ± 16.91H	518.88 ± 13.43N	418.36 ± 10.59S	427.77 ± 11.77S	62.21 ± 2.79U
		Yağlık	430.93 ± 11.66S	472.47 ± 10.08QR	412.55 ± 4.86S	501.34 ± 8.63NOP	479.63 ± 4.65PQR	458.73 ± 6.35R
	Irrigated	Ayvalık	822.69 ± 7.74D	578.08 ± 19.73JK	707.99 ± 13.77EFG	949.13 ± 69.31A	882.26 ± 18.79C	825.44 ± 12.89D
		Çöpaşı	422.95 ± 7.76S	497.71 ± 17.06NOPQ	523.12 ± 10.68MN	508.76 ± 11.75NO	545.92 ± 10.14LM	559.05 ± 12.08KL
		Gemlik	922.84 ± 20.78B	615.80 ± 15.08H	908.43 ± 13.34B	731.60 ± 10.49E	918.95 ± 9.69B	717.43 ± 14.41EF
		Yağlık	611.89 ± 12.40HI	558.04 ± 11.36KL	682.40 ± 7.50G	721.31 ± 3.47EF	617.20 ± 16.89H	708.60 ± 12.16EFG

	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
K	Rainfed	Ayvalık	6189.24 ± 121.88I	5456.85 ± 77.10L	4327.20 ± 43.49QRS	5382.33 ± 90.35L	5061.32 ± 72.70M	5429.23 ± 81.72L
		Çöpaşı	5070.22 ± 81.71M	4887.46 ± 102.19N	4907.55 ± 89.82N	3897.04 ± 119.69V	4262.90 ± 65.85S	3718.04 ± 67.14W
		Gemlik	6609.25 ± 105.71H	4403.94 ± 45.95Q	4308.80 ± 47.51RS	4047.86 ± 67.64U	3699.14 ± 134.39W	157.11 ± 20.30Y
		Yağlık	4603.69 ± 30.56P	5022.28 ± 31.47M	4171.58 ± 86.44T	3900.08 ± 126.01V	4319.80 ± 61.63QRS	5071.80 ± 75.60M
	Irrigated	Ayvalık	8203.25 ± 124.46B	4295.60 ± 128.06S	4587.05 ± 80.50P	6788.40 ± 88.38G	6183.61 ± 33.03I	4824.50 ± 62.54NO
		Çöpaşı	5800.93 ± 127.81J	5813.16 ± 25.30J	5022.74 ± 33.44M	5000.56 ± 28.42M	2484.68 ± 107.66X	5569.89 ± 81.11K
		Gemlik	7577.77 ± 52.42C	6133.63 ± 58.65I	7472.15 ± 48.23D	5866.99 ± 57.30J	8398.34 ± 59.33A	7293.32 ± 105.03F
		Yağlık	7381.56 ± 85.95E	4786.94 ± 79.57O	4394.02 ± 91.15QR	4642.73 ± 76.83P	4254.90 ± 76.71ST	4043.64 ± 60.61U

P: Phosphorus, K: Potassium

Mean (three replicates) ± standard deviation of each parameter

Different superscript letters in the same row indicate significant differences (p <0.01) were compared with Duncan test

Table 2. (continued) Mineral contents of olive leaves

	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
Ca	Rainfed	Ayvalık	12906.85 ± 116.38-	16865.92 ± 78.09W	19995.92 ± 15.46M	21375.42 ± 88.81I	21410.19 ± 63.11I	19822.46 ± 63.34NO
		Çöpaşı	18692.60 ± 113.61R	21067.22 ± 77.24J	21653.51 ± 68.01H	21097.23 ± 85.58J	23110.60 ± 93.39F	22673.90 ± 102.62G
		Gemlik	17798.26 ± 104.93T	17858.57 ± 65.83T	21614.31 ± 109.79H	19881.20 ± 65.16N	18886.87 ± 48.34Q	1487.58 ± 35.18’
		Yağlık	20696.92 ± 119.47K	15038.02 ± 53.63[	14669.77 ± 82.01/	19769.36 ± 80.17O	21575.05 ± 91.11H	23482.32 ± 89.68E
	Irrigated	Ayvalık	15953.60 ± 213.90Y	20481.69 ± 110.43L	20067.68 ± 75.46M	14360.11 ± 68.02]	14106.64 ± 147.35^	14694.82 ± 161.74/
		Çöpaşı	18060.19 ± 78.84S	16807.57 ± 88.46W	17373.25 ± 99.19U	17796.55 ± 90.95T	19155.16 ± 68.88P	16788.62 ± 111.97W
		Gemlik	27568.65 ± 82.60B	31115.73 ± 99.09A	26775.19 ± 85.59B	27570.25 ± 49.58B	27431.28 ± 85.72C	24384.84 ± 102.22D
		Yağlık	12870.53 ± 90.74-	14110.13 ± 119.76^	14031.10 ± 43.95I^	16660.70 ± 81.36X	15762.99 ± 62.83Z	17067.51 ± 65.32V

	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
Mg	Rainfed	Ayvalık	1505.13 ± 32.53V	2023.07 ± 28.95NO	2172.77 ± 95.91HIJK	1997.38 ± 41.43O	2039.22 ± 44.87NO	1866.44 ± 37.80PQ
		Çöpaşı	1714.04 ± 21.55S	1611.68 ± 89.26T	1722.34 ± 89.23S	1542.72 ± 79.10TUV	1410.82 ± 102.10W	1914.24 ± 66.45P
		Gemlik	2227.44 ± 45.76GHI	2222.26 ± 36.47GHI	1744.11 ± 77.29RS	1615.68 ± 69.86T	1810.95 ± 38.76QR	111.04 ± 12.29X
		Yağlık	1560.63 ± 134.65TUV	1610.42 ± 35.38T	1523.03 ± 102.76UV	1524.08 ± 72.69UV	1603.61 ± 61.45TU	2006.99 ± 9.80O
	Irrigated	Ayvalık	3394.94 ± 133.47A	2060.59 ± 84.72MNO	2226.35 ± 82.43GHI	2383.53 ± 108.70D	2187.32 ± 44.20GHIJ	2354.04 ± 74.94D
		Çöpaşı	2150.04 ± 69.64IJKL	2131.61 ± 37.60JKLM	2341.19 ± 71.88D	2266.63 ± 72.33EFG	3042.20 ± 48.15B	2253.94 ± 69.21FGH
		Gemlik	2329.95 ± 63.46DEF	2373.15 ± 69.37D	2539.53 ± 75.42C	2073.48 ± 82.58LMNO	2269.40 ± 83.24EFG	2387.77 ± 80.74D
		Yağlık	1901.40 ± 29.41P	2033.12 ± 41.03NO	1914.15 ± 33.47P	2033.39 ± 27.02NO	2101.71 ± 37.75KLMN	2184.13 ± 96.94GHIJ

Ca: Calcium, Mg: Magnesium
Mean (three replicates) ± standard deviation of each parameter
Different superscript letters in the same row indicate significant differences (p <0.01) were compared with Duncan test

Table 2. (continued) Mineral contents of olive leaves

	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
S	Rainfed	Ayvalık	1204.26 ± 99.24JK	1362.21 ± 59.06EFG	1307.37 ± 58.39GH	1392.03 ± 90.47EF	1228.83 ± 83.20IJ	1292.00 ± 51.19HI
		Çöpaşı	1195.69 ± 70.74JK	1282.78 ± 70.56HI	1392.59 ± 96.87EF	1127.55 ± 54.98LMN	1088.62 ± 57.78LMNO	1311.10 ± 65.08GH
		Gemlik	1311.69 ± 47.53GH	1155.30 ± 64.83KL	1003.98 ± 13.94P	891.19 ± 110.58Q	1098.83 ± 76.90LMNO	120.97 ± 26.70R
		Yağlık	1086.29 ± 89.79MNO	1071.26 ± 55.35NO	1090.12 ± 64.42LMNO	1044.34 ± 65.40OP	1077.25 ± 61.16MNO	1141.73 ± 61.04KLM
	Irrigated	Ayvalık	1580.57 ± 94.76BC	1314.88 ± 82.01GH	1392.68 ± 123.36EF	1502.33 ± 34.27D	1386.69 ± 86.40EF	1308.40 ± 60.11GH
		Çöpaşı	1082.54 ± 52.38MNO	1090.05 ± 75.66LMNO	1096.09 ± 73.60LMNO	1197.88 ± 38.79JK	1099.21 ± 80.84LMNO	1054.97 ± 71.28OP
		Gemlik	1679.05 ± 94.03A	1401.63 ± 48.33EF	1676.04 ± 88.81A	1534.55 ± 74.18CD	1608.68 ± 85.02B	1318.49 ± 76.08GH
		Yağlık	1515.52 ± 91.70D	1396.48 ± 96.20EF	1337.12 ± 80.41FGH	1241.69 ± 72.31IJ	1285.17 ± 105.83HI	1410.05 ± 53.69E

	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
Na	Rainfed	Ayvalık	211.45 ± 2.52CD	241.11 ± 7.95A	176.69 ± 6.00JKL	158.16 ± 3.86OP	186.14 ± 7.52FGH	156.46 ± 7.40OP
		Çöpaşı	156.10 ± 6.73OP	180.27 ± 3.85HIJ	227.29 ± 7.42B	152.43 ± 9.56PQ	137.43 ± 4.35UVW	140.50 ± 11.33STUV
		Gemlik	171.17 ± 5.11LM	178.84 ± 6.05IJ	176.75 ± 7.65JKL	133.40 ± 8.92VW	151.85 ± 5.90PQ	3.42 ± 0.58Z
		Yağlık	237.65 ± 3.93A	192.07 ± 5.18F	147.81 ± 5.70QR	122.54 ± 5.15X	187.51 ± 4.51FG	147.27 ± 9.63QRS
	Irrigated	Ayvalık	216.16 ± 15.59C	208.24 ± 11.43DE	131.68 ± 10.37W	185.66 ± 6.31FGHI	143.18 ± 9.51RSTU	137.66 ± 11.00UVW
		Çöpaşı	170.50 ± 9.96LM	178.46 ± 8.64JK	136.72 ± 5.56UVW	160.91 ± 2.22NO	69.88 ± 6.29Y	156.19 ± 8.27OP
		Gemlik	202.50 ± 8.56E	151.41 ± 10.11PQ	122.46 ± 8.64X	161.53 ± 8.56NO	171.57 ± 7.54KLM	181.01 ± 6.59GHIJ
		Yağlık	167.30 ± 9.69MN	188.97 ± 8.92F	138.98 ± 12.13TUV	120.44 ± 9.38X	145.69 ± 7.67QRST	123.35 ± 8.34X

S: Sulphur, Na: Sodium
Mean (three replicates) ± standard deviation of each parameter
Different superscript letters in the same row indicate significant differences (p <0.01) were compared with Duncan test

Table 2. (continued) Mineral contents of olive leaves

	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
Fe	Rainfed	Ayvalık	77.23 ± 9.45RS	128.58 ± 4.26FGHIJ	119.45 ± 5.35IJKL	131.90 ± 5.80EFGHI	158.54 ± 10.80C	138.01 ± 4.91DEFG
		Çöpaşı	98.87 ± 8.61MNOPQ	121.00 ± 7.52HIJK	146.90 ± 6.80CDE	122.00 ± 8.94GHIJK	88.24 ± 8.97PQR	83.46 ± 6.33QRS
		Gemlik	98.72 ± 11.36MNOPQ	95.46 ± 9.91NOPQ	136.88 ± 8.75DEFGH	95.52 ± 7.01NOPQ	150.20 ± 9.55CD	13.22 ± 0.28T
		Yağlık	129.20 ± 3.75FGHI	131.74 ± 5.24EFGHI	128.56 ± 8.79FGHIJ	87.10 ± 9.40PQR	96.65 ± 8.24MNOPQ	105.51 ± 6.83KLMNO
	Irrigated	Ayvalık	103.58 ± 7.30LMNOP	139.87 ± 10.18DEF	100.00 ± 7.01MNOPQ	89.72 ± 8.87OPQR	70.71 ± 12.15S	86.98 ± 8.13PQR
		Çöpaşı	119.57 ± 6.39IJKL	119.27 ± 9.49IJKL	91.33 ± 9.10OPQR	142.23 ± 10.87DEF	119.16 ± 3.48IJKL	132.62 ± 5.04EFGHI
		Gemlik	127.74 ± 4.02FGHIJ	305.36 ± 38.64A	88.60 ± 9.82PQR	160.43 ± 11.42C	199.62 ± 4.02B	112.13 ± 8.04JKLM
		Yağlık	140.65 ± 12.01DEF	146.26 ± 7.93CDE	140.58 ± 11.19DEF	118.12 ± 4.86IJKL	160.25 ± 10.82C	109.27 ± 3.52KLMN

	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
Cu	Rainfed	Ayvalık	11.15 ± 1.00LMNOPQR	14.09 ± 0.59E	13.02 ± 0.95FG	11.12 ± 0.63LMNOPQR	12.00 ± 0.90IJKLM	55.26 ± 0.79A
		Çöpaşı	10.37 ± 0.59QRST	11.14 ± 1.12LMNOPQR	14.33 ± 0.91DE	11.25 ± 0.47LMNOPQ	10.79 ± 0.33PQRST	12.04 ± 0.93HIJKL
		Gemlik	12.18 ± 0.14GHIJK	11.68 ± 0.93KLMNOP	13.01 ± 0.48FG	10.22 ± 0.45RST	11.63 ± 0.84KLMNOP	0.95 ± 0.01V
		Yağlık	13.18 ± 0.56F	10.85 ± 0.40PQRS	9.92 ± 1.22T	10.25 ± 0.81RST	12.92 ± 0.51FGH	12.19 ± 1.04GHIJK
	Irrigated	Ayvalık	14.11 ± 0.64E	12.99 ± 0.41FG	10.90 ± 0.64OPQRS	15.04 ± 1.14D	11.83 ± 1.05JKLMNO	53.84 ± 1.16B
		Çöpaşı	11.01 ± 1.09NOPQRS	11.05 ± 0.95MNOPQR	10.21 ± 1.07RST	11.12 ± 0.78LMNOPQR	7.37 ± 0.49U	12.74 ± 0.26FGHIJ
		Gemlik	13.59 ± 0.71EF	12.87 ± 1.06FGHI	13.10 ± 0.42FG	13.10 ± 0.91FG	13.18 ± 0.82F	28.66 ± 0.80C
		Yağlık	11.69 ± 0.49KLMNOP	11.96 ± 1.22IJKLMN	10.62 ± 0.74QRST	9.91 ± 0.32T	11.23 ± 0.88LMNOPQ	10.09 ± 0.86ST

Fe: Iron, Cu: Copper Mean (three replicates) ± standard deviation of each parameter Different superscript letters in the same row indicate significant differences (p <0.01) were compared with Duncan test

Table 2. (continued) Mineral contents of olive leaves

	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
Mn	Rainfed	Ayvalık	22.13 ± 0.81P	24.97 ± 0.27N	29.94 ± 0.54J	28.99 ± 0.48UV	26.65 ± 0.79UV	20.77 ± 0.57UV
		Çöpaşı	17.22 ± 0.62X	20.23 ± 0.94ST	22.23 ± 1.03P	18.65 ± 0.92P	18.76 ± 0.74Z	19.22 ± 0.45[
		Gemlik	19.25 ± 0.84UV	46.73 ± 1.01E	19.91 ± 0.18TU	22.39 ± 0.83Y	14.75 ± 0.42R	2.77 ± 0.14W
		Yağlık	17.02 ± 0.61X	17.22 ± 0.59X	14.10 ± 0.40Z	15.67 ± 0.78J	21.04 ± 1.10I	18.40 ± 0.69K
	Irrigated	Ayvalık	21.01 ± 0.50R	19.10 ± 1.17VW	24.19 ± 0.57O	30.16 ± 0.83G	31.98 ± 1.27A	29.07 ± 0.30H
		Çöpaşı	45.99 ± 0.30F	47.21 ± 0.91E	49.34 ± 0.76D	42.76 ± 0.47L	61.17 ± 0.86G	34.15 ± 0.91H
		Gemlik	54.18 ± 0.45B	51.06 ± 0.71C	25.23 ± 0.94N	27.13 ± 0.49M	42.64 ± 0.85QR	28.92 ± 0.42K
		Yağlık	17.09 ± 0.73X	21.25 ± 0.64QR	20.10 ± 0.45ST	26.08 ± 0.88LM	21.20 ± 0.75RS	21.90 ± 0.64PQ
	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
Zn	Rainfed	Ayvalık	9.44 ± 0.62PQR	11.03 ± 0.82NO	11.05 ± 0.98NO	10.02 ± 0.93P	11.23 ± 0.61NO	10.02 ± 0.81P
		Çöpaşı	7.15 ± 0.99V	8.49 ± 0.66ST	8.51 ± 0.67ST	7.38 ± 0.48UV	8.67 ± 0.73RST	7.19 ± 0.90UV
		Gemlik	10.95 ± 0.55O	9.94 ± 0.71P	9.00 ± 0.77QRS	8.96 ± 0.87RS	9.80 ± 0.77PQ	0.96 ± 0.01W
		Yağlık	7.21 ± 0.78UV	6.93 ± 0.69V	8.49 ± 0.69ST	6.88 ± 0.47V	8.01 ± 0.75TU	7.15 ± 1.14V
	Irrigated	Ayvalık	24.03 ± 0.35B	14.93 ± 0.36I	13.87 ± 0.44JK	13.68 ± 1.74JKL	12.96 ± 0.83L	16.88 ± 0.98GH
		Çöpaşı	23.06 ± 0.70C	19.15 ± 0.54EF	18.44 ± 0.73F	16.80 ± 0.37GH	19.92 ± 0.50E	14.30 ± 0.87IJ
		Gemlik	20.90 ± 1.00D	17.15 ± 0.52G	16.21 ± 1.07H	27.07 ± 0.57A	17.30 ± 0.56G	11.84 ± 0.58MN
		Yağlık	11.86 ± 0.26MN	19.14 ± 0.82EF	19.74 ± 0.96E	13.13 ± 0.97KL	14.34 ± 0.66IJ	12.14 ± 0.69M

Mn: Manganese, Zn: Zinc
Mean (three replicates) ± standard deviation of each parameter
Different superscript letters in the same row indicate significant differences (p <0.01) were compared with Duncan test

Table 2. (continued) Mineral contents of olive leaves

	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
B	Rainfed	Ayvalık	12.20 ± 0.90JK	13.11 ± 0.62I	12.21 ± 0.71JK	13.28 ± 0.07HI	13.08 ± 0.75I	14.05 ± 0.55GH
		Çöpaşı	9.46 ± 0.49RS	10.08 ± 1.22PQRS	8.50 ± 0.69T	9.35 ± 0.43S	9.88 ± 0.31QRS	9.59 ± 0.26QRS
		Gemlik	13.95 ± 0.21GH	10.89 ± 0.71MNO	11.95 ± 0.64KL	9.24 ± 0.47S	9.98 ± 0.51QRS	0.95 ± 0.01U
		Yağlık	13.96 ± 0.82GH	10.85 ± 0.40MNOP	10.25 ± 0.75OPQR	11.12 ± 0.85LMN	9.40 ± 0.13S	12.26 ± 0.93JK
	Irrigated	Ayvalık	22.90 ± 0.57A	14.92 ± 0.37F	12.90 ± 0.48IJ	11.65 ± 0.67KLM	11.14 ± 0.67LMN	11.13 ± 0.82LMN
		Çöpaşı	11.17 ± 0.86LMN	9.40 ± 0.53S	9.49 ± 0.69RS	9.46 ± 0.59RS	8.35 ± 0.48T	11.24 ± 0.98LM
		Gemlik	16.86 ± 0.22D	20.10 ± 0.47B	19.04 ± 0.85C	15.01 ± 0.79F	16.25 ± 0.66DE	15.55 ± 0.66EF
		Yağlık	20.08 ± 0.43B	14.18 ± 0.87G	11.92 ± 0.20KL	10.98 ± 0.11MNO	10.39 ± 0.66NOPQ	12.15 ± 0.68JK
	Process	Variety	1st Harvest	2nd Harvest	3rd Harvest	4th Harvest	5th Harvest	6th Harvest
Ni	Rainfed	Ayvalık	0.99 ± 0.01GH	1.80 ± 0.21F	2.76 ± 0.25CD	1.62 ± 0.23F	2.87 ± 0.07CD	2.82 ± 0.11CD
		Çöpaşı	2.72 ± 0.32CD	2.71 ± 0.38CD	3.44 ± 0.78AB	2.62 ± 0.39CD	2.44 ± 0.44D	3.76 ± 0.22A
		Gemlik	1.84 ± 0.08F	0.94 ± 0.01H	0.00 ± 0.00I	0.95 ± 0.01H	0.92 ± 0.03H	0.00 ± 0.00I
		Yağlık	3.78 ± 0.14A	0.92 ± 0.01H	1.78 ± 0.04F	2.70 ± 0.00CD	2.73 ± 0.18CD	2.89 ± 0.13CD
	Irrigated	Ayvalık	3.49 ± 0.55AB	1.48 ± 0.59FG	1.45 ± 0.63FGH	0.91 ± 0.04H	1.66 ± 0.39F	3.46 ± 0.62AB
		Çöpaşı	1.69 ± 0.18F	1.81 ± 0.21F	1.90 ± 0.15EF	1.61 ± 0.27F	2.69 ± 0.30CD	2.76 ± 0.31CD
		Gemlik	2.51 ± 0.44CD	3.75 ± 0.21A	2.37 ± 0.45DE	2.42 ± 0.47D	3.04 ± 1.27BC	2.46 ± 0.53CD
		Yağlık	2.83 ± 0.06CD	1.81 ± 0.23F	1.65 ± 0.30F	1.63 ± 0.30F	1.82 ± 0.23F	1.81 ± 0.18F

B: Boron, Ni: Nickel
Mean (three replicates) ± standard deviation of each parameter
Different superscript letters in the same row indicate significant differences (p <0.01) were compared with Duncan test

Statistical analysis

Statistical analyses of the results were performed by using SPSS-Statistics-22 statistical program. The means of significant variation sources were compared to Duncan Multiple Comparison Test with the help of MSTAT program. The significance level is given as p <0.01 unless otherwise stated.

Results and Discussion

Mineral contents of olive leaves belonging to Ayvalık, Çöpaşı, Gemlik and Yağlık varieties collected different times are given in Table 2. The phosphorus (P) content varied between 578.08 mg/kg and 949.13 mg/kg for Ayvalık leaves; 331.25 mg/kg and 571.75 mg/kg for Çöpaşı leaves; 62.21 mg/kg and 922.84 mg/kg for Gemlik leaves; 412.55 mg/kg and 721.31 mg/kg for Yağlık leaves. In a study performed by Paskovic et al. (2020), P contents of olive leaves belonging to five different varieties varied between 1.36 and 1.67 g/kg, which was lower than the current study. In another study, the highest and lowest levels of P were recorded in olive leaves belonging to Gemlik (1.6-2.0 g/kg) and Savrani (1.1-1.4 g/kg) varieties (Toplu et al., 2009). The highest and lowest P amounts were found in Ayvalık leaves (949.13 mg/kg) collected on November 17th (4th harvest), and Gemlik leaves (62.21 mg/kg) collected on December 29th (6th harvest), respectively. The fluctuations were observed in P contents of leaves during the collection period, although Çöpaşı leaves showed a regular increase in P levels when the collection time progressed from 1st harvest to 6th harvest. Similarly, P amounts of Kilis Yağlık and Gemlik varieties did not show a regular increase or decrease (Cetinkaya et al., 2016). In another study, the amounts of P were similar at collection period-1 (October 2017) and collection period-2 (January 2018), however, it was lower at collection period-3 (March 2018) (Lukic et al., 2020). Generally, irrigation treatment increased P contents of olive leaves, and the highest increase from 62.21 mg/kg to 717.43 mg/kg was determined in Gemlik leaves collected on December 29th with irrigation process. Çetinkaya et al. (2016) informed that arid conditions caused lower accumulation of P.

The potassium (K) contents of Ayvalık, Çöpaşı, Gemlik and Yağlık olive leaves were equal to 4295.60-8203.25 mg/kg, 2484.68-5813.16 mg/kg, 157.11-8398.34 mg/kg and 3900.08-7381.56 mg/kg, respectively. Similar K contents (5.28-7.85 g/kg) were recorded by Paskovic et al. (2020). The highest K amount was detected in Gemlik variety (8398.34 mg/kg) picked on December 8th (5th harvest) from irrigated trees. Additionally, a regular reduction was obtained in K contents of rainfed Gemlik leaves during the whole collection period, and irrigation led to increase (from 157.11 mg/kg to 7293.32 mg/kg in especially last collection time) in this mineral for all harvest dates. This result was in accordance with the study of Çetinkaya et al. (2016), which recorded that the limited water amount caused a reduction in the availability of K. Similarly, in another study, it was recorded that the availability of K in soil was limited in non-irrigated olive orchards (Fernandez-Escobar et al., 1999). An increase was observed with irrigation treatment for other leaf varieties, except Ayvalık and Yağlık leaves collected on October 6th and December 29th; Çöpaşı and Yağlık leaves picked on December 8th.

Olive leaves were a significant source of the calcium (Ca), ranging from 12906.85 mg/kg to 21410.19 mg/kg in Ayvalık; from 16788.62 mg/kg to 23110.60 mg/kg in Çöpaşı; from 1487.58 mg/kg to 31115.73 mg/kg in Gemlik; from 12870.53 mg/kg to 23482.32 mg/kg in Yağlık leaves. The high amounts of Ca are generally determined in olive leaves of Mediterranean region due to calcareous soils (Toplu et al., 2009). In a previous study, Ca contents of olive leaves were found as 25.07 g/kg for Drobnica; 19.59 g/kg for Istarska bjelica; 22.19 g/kg for Leccino; 17.50 g/kg for Levantinka; 11.45 g/kg for Oblica (Paskovic et al., 2020). Harvest time caused a significant difference in Ca concentration of olive leaves (p<0.01). Moreover, irrigation process reduced the amounts of Ca in the Çöpaşı and Yağlık leaves, while irrigation application increased the Ca contents of the Gemlik leaves during collection period. For Ayvalık leaves, an increase in first three harvest, and a

decrease the last three harvest were determined. Opposite to that Ca content of Gemlik variety increased in non-irrigation conditions (Cetinkaya et al., 2016).

The magnesium (Mg) amounts of Ayvalık, Çöpaşı, Gemlik and Yağlık olive leaves were recorded between 1505.13 mg/kg and 3394.94 mg/kg, 1410.82 mg/kg and 3042.20 mg/kg, 111.04 mg/kg and 2539.53 mg/kg, 1523.03 mg/kg and 2184.13 mg/kg, respectively. The Mg contents of irrigated Ayvalık, Çöpaşı, Gemlik and Yağlık leaves were higher than the rainfed samples in all harvests. However, no regular increase or decrease was obtained in the Mg amounts along with the collection period. Similarly, Mg concentrations of leaves, which were higher than the current study, were equal to 8.53 g/kg, 9.59 g/kg and 9.56 g/kg when collected on October 2017, January 2018 and March 2018, respectively (Paskovic et al., 2020). In another study, Mg amounts of olive leaves belonging to Madural, Verdeal and Cobrançosa varieties were recorded as 1.02 g/kg, 1.58 g/kg and 0.88 mg/kg, respectively (de Oliveira et al., 2023). In a study recorded by Christos et al. (2005), the concentration of Mg exhibited seasonal change in the value of 1.0-2.0 g/kg.

The highest sulphur (S) contents were recorded as 1580.57 mg/kg, 1679.05 mg/kg and 1515.52 mg/kg in Ayvalık, Gemlik and Yağlık leaves collected in irrigated orchard on September 15th, respectively, whereas the maximum S amount of Çöpaşı leaves was found as 1392.59 mg/kg when leaves were collected in rainfed orchard on October 27th. Moreover, it was determined that irrigation process increased the S contents of leaves belonged to Gemlik and Yağlık varieties.

The sodium (Na) contents were ascertained between 131.68 mg/kg and 241.11 mg/kg in Ayvalık; 69.88 mg/kg and 227.29 mg/kg in Çöpaşı; 3.42 mg/kg and 202.50 mg/kg in Gemlik; 120.44 mg/kg and 237.65 mg/kg in Yağlık leaves. In a previous study, Toplu et al. (2009) revealed that the highest and lowest Na contents were equal to 450 mg/kg in olive leaves of Kilis Yağlık variety and 320 mg/kg in leaves of Gemlik variety. The Na contents of Yağlık leaves showed a reduction during harvest period for rainfed and 53.84 mg/kg for irrigated trees), and the amounts of this element reached their when irrigation process was applied, while a major increase from 3.42 mg/kg to 181.01 mg/kg was observed in Gemlik leaves collected on December 29th. There are considerably differences in the levels of Na based on collection date. Na contents of olive leaves can show differences between 100 and 300 mg/kg in regard to the cultivar (Loupassaki et al., 2002).

The iron (Fe) contents of Ayvalık, Çöpaşı, Gemlik and Yağlık olive leaves ranged from 70.71 mg/kg to 158.54 mg/kg; from 83.46 mg/kg to 146.90 mg/kg; from 13.22 mg/kg to 305.36 mg/kg; from 87.10 mg/kg to 160.25 mg/kg, respectively. According to the study of Paskovic et al. (2020), olive leaves contained lower amounts of Fe (68.24-88.95 mg/kg) than the current results. The Fe amounts of Yağlık leaves collected in irrigated orchard were higher than those of rainfed samples. On the other hand, the effect of irrigation on Fe contents of Ayvalık, Çöpaşı and Gemlik leaves showed differences in regard to sampling date. Muthuchelien et al. (1997) informed that reduction in iron amount is related to peroxidase activity reduced with irrigation.

In addition to these elements, olive leaves contained copper (Cu, 0.95-55.26 mg/kg), manganese (Mn, 2.77-61.17 mg/kg), zinc (Zn, 0.96-27.07 mg/kg), boron (B, 0.95-22.90 mg/kg) and nickel (Ni, 0.00-3.78 mg/kg) in minor amounts. The concentrations of these elements varied depending on the sampling time, however, there is no any regular increase or decrease was determined. In a study, published by Paskovic et al. (2020), Zn, Mn, Cu and B amounts of olive leaves belonging to different varieties were reported as 22.17-25.85 mg/kg, 46.74-67.68 mg/kg, 11.09-16.19 mg/kg and 15.78-18.28 mg/kg, respectively. It was informed that seasonal differences can be observed in Mn contents of olive leaves with the range of 14.0–52.8 mg/kg (Christos et al., 2005). In another study, Mn, Zn and Cu concentrations of olive leaves were reported as 22.3-34.52 mg/kg, 14.3-27.2 mg/kg and 11.0-25.0 mg/kg, respectively (Toplu et al., 2009). The highest Cu content in current study was observed in Ayvalık leaves (55.26 mg/kg

maximum levels when collected on December 29th for both orchards. Moreover, irrigation

caused a significant increase in Mn and Zn elements, especially in Çöpaşı and Gemlik varieties. Similarly, B and Ni amounts of irrigated Gemlik leaves were higher than those of rainfed samples during collection period.

Regarding to the effect of irrigation on P, K, Mg, Ca contents of olive leaves, a similar increase was informed due to higher mobility in soils and enhance transportion of these elements to the leaves with irrigation process (Bie et al., 2004; Koyro, 2006; Wu and Xia, 2006; Cetinkaya et al., 2016). Moreover, the water stress conditions decrease in leaf area because of leaf shrinkage and also cause reduction in some elements such as N, P, K, Ca, Na, Cl in olive leaves (Shaheen et al., 2011). Similarly, in another study, the results revealed that the macro and micro element compositions of irrigated leaves belonged to *cv*. Gemlik were better than rainfed samples (Cetinkaya et al., 2016).

Conclusion

The macro and micro element contents of olive leaves were significantly affected from variety, irrigation treatment and collection time. Olive leaf was a significant source of macro elements such as P, K, Ca, Mg and S. Additionally, olive leaves contained in minor amounts of Na, Fe, Cu, Mn, Zn, B and Ni. The lowest macro and micro element contents were observed in olive leaves belonging to Gemlik variety collected on December 29th. The irrigation treatments positively affected especially cv. Gemlik but it should be noted that the concentration of macro and micro elements varied differently according to the sampling times. For olive leaves of Ayvalık, Yağlık and Çöpaşı varieties, the effect of irrigation treatment on mineral contents varied according to collection time. Therefore, it was not easy to make a general comment because of fluctuation in mineral amounts during collection period.

References

Bartels, D., Sunkar, R. (2005) Drought and salt tolerance in plants. *Crit Rev Plant Sci* 24:23-58.

Bedbabis, S., Rouina, B. B., Clodoveo, M. L., Ferrara, G. (2016) 'Chemlali' olive trees in an irrigated grove: effects of tree age on virgin olive oil quality and mineral nutrient distributio in roots, leaves and fruits. *Fruits* 71(4): 21-228.

Bie, Z., Ito, T., Shinohara, Y. (2004) Effects of sodium sulphate and sodium bicarbonate on the growth, gas exchange and mineral composition of lettuce. *Sci Hortic* 99:215–224.

Bongi, G., Palliotti, A. (1994) Olive. In: *Handbook of Environmental Physiology of Fruit Crops: Temperate Crops*. B. Shaffer and P. C. Anderson (Eds.), 165-187, CRC Press, Boca Raton.

Cetinkaya, H., Koc, M., Kulak, M. (2016) Monitoring of mineral and polyphenol content in olive leaves under drought conditions: Application chemometric techniques. *Ind Crops Prod* 88:78-84.

Christos, A. C., Ioannis, N. T., Athanassios, N. M. (2005) Seasonal variation of nutritional status of olive plants as affected by boron concentration in nutrient solution. *J Plant Nutr* 28:30-321.

de Oliveira, N. M., Lopes, L., Cheu, M. H., Soares, E., Meireles, D., Machado, J. (2023) Updated Mineral Composition and Potential Therapeutic Properties of Different Varieties of Olive Leaves from *Olea europaea.* Plants 12:1-8.

Dimassi, K., Therios, I., Passalis, A. (1999) Genotypic effect on leaf mineral levels of 17 olive cultivars grown in Greese. *Acta Hortic* 474:345-8.

Fernandez-Escobar, R., Moreno, R., Garcia-Creus, M. (1999) Seasonal changes of mineral nutrients in olive leaves during the alternate-bearing cycle. *Sci Hortic* 82: 25–45.

Grattan, S. R., Grieve, C. M. (1999) Salinity mineral nutrient relations in horticultural crops. *Sci Hortic* 78: 127-157.

Jordao, P. V., Marcelo, M. E., Centeno, M. S. L. (1999) Effect of cultivar on leaf-mineral composition of olive tree. *Acta Hortic* 474:349-52.

Koyro, H. W. (2006) Effect of salinity on growth, photosynthesis, water relations and solute composition of the potential

cash crop halophyte (Plantago coronopus L.). *Environ Exp Bot* 56:136-146.

Loupassaki, M. H., Chartzoulakis, K. S., Digalaki, N. B., Androulakis, I. (2002) Effects of salt stress on concentratıon of nitrogen, phosphorus, potassıum, calcıum, magnesıum, and sodium in leaves, shoots, and roots of six olive cultivars. *J Plant Nutr* 25:2457-2482.

Łozak, A., Sołtyk, K., Ostapczuk, P., Fijałek, Z. (2002) Determination of selected trace elements in herbs and their infusions. *Sci Total Environ* 289:33-40.

Lukic, I., Paskovic, I., Zurga, P., Germek, V. M., Brkljaca, M., Marcelic, S., Ban, D., Grozic, K., Lukic, M., Uzila, Z., Ban, S. G. (2020) Determination of the variability of biophenols and mineral nutrients in olive leaves with respect to cultivar, collection period and geographical location for their targeted and well-timed exploitation. *Plants* 9:1-20.

Molina-Alcaide, E., Yáñez-Ruiz, D. R. (2008) Potential use of olive by-products in ruminant feeding: a review. *Anim Feed Sci Technol* 147:247-264.

Muthuchelian, K., Murugan, C., Nedunchezhianand, N., Kulandaivelu, G. (1997) Photosynthesis and growth of Erythrina variegata as affected by water stress and triacantanol. *Photosynthetica* 33:241-248.

Ozyigit, I. I., Yalcin, B., Turan, S., Saracoglu, I. A., Karadeniz, S., Yakcin, I. A., Demir, G. (2018) Investigation of Heavy Metal Level and Mineral Nutrient Status in Widely Used Medicinal Plants' Leaves in Turkey: Insights into Health Implications. *Biol Trace Elem Res* 182:387-406.

Özcan, M. M., Matthaus, B. (2017) A review: benefit and bioactive properties of olive (*Olea europaea* L.) leaves. *Eur Food Res Technol* 243:89-99.

Paskovic, I., Lukic, I., Zurga, P., Germek, V. M., Brkljaca, M., Koprivnjak, O., Major, N., Grozic, K., Franic, M., Ban, D., Marcelic, S., Ban, S. G. (2020) Temporal Variation of Phenolic and Mineral Composition in Olive Leaves Is Cultivar Dependent. *Plants* 9:1-16.

Shaheen, M. A., Hegazi, A. A., Hmmam, I. S. (2011) Effect of water stress on vegetative characteristics and leaves chemical constituents of some transplants olive cultivars American-Eurasian. *J Agric Environ Sci* 11:663–670.

Toplu, C., Uygur, V. Yildiz, E. (2009) Leaf mineral composition of olive varieties and their relation to yield and adaptation ability. *J Plant Nutr* 32:1560-73.

Tošic, S. B., Mitic, S. S., Velimirovic, D. S., Stojanovic, G. S., Pavlovic, A. N., Pecev-Marinkovic, E. T. (2015) Elemental composition of edible nuts: fast optimization and validation procedure of an ICP-OES method. *J Sci Food Agric* 95:2271-2278.

Wu, Q., Xia, R. (2006) Arbuscular mycorrhizal fungi influence growth: osmotic adjustment and photosynthesis of citrus under well-watered and water stress conditions. *J Plant Physiol* 163:417-425.

Yousif, B. S., Nguyen, N. T., Fukuda, Y., Hakata, H., Okamoto, Y., Masaoka, Y., Saneoka, H. (2010) Effect of salinity on growth mineral composition, photosynthesis and water relations of two vegetable crops; New Zealand spinach (*Tetragonia tetragonioides*) and water spinach (*Ipomoea aquatica*). *Int J Agric Biol* 12:211-216.

Zohary, D., Hopf, M., Weiss, E. (2012) Domestication of Plants in the Old World: *The Origin and Spread of Domesticated Plants in Southwest Asia, Europe, and the Mediterranean Basin*. 116–121, Oxford University Press, Oxford, UK