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ABSTRACT

The amount of yield and adaptation of a cultivar to a new environment is strongly related to nutrient uptake ability. The aim of this study was to compare nutrient uptake ability of 21 local and/or standard olive varieties grown under Mediterranean climatic conditions. Elemental compositions of olive leaves were determined for two consecutive years. The highest yields were obtained from 'Gemlik', 'Manzanilla', 'Memecik', and 'Hojiblanca' varieties. Nitrogen (N), phosphorus (P), potassium (K), magnesium (Mg), and manganese (Mn) content of leaves were comparatively higher in the high-yielding year (2004) whereas iron (Fe) and copper (Cu) contents were lower. Nutrient uptake ability and usage efficiency of olive varieties were different. Mineral composition of leaves was variety dependent and different groups of varieties showed higher leaf concentration for each element. Therefore, it can be concluded that the variation in the nutrient uptake ability may be used as a criterion for adaptation of a variety to a new ecological environment.

Keywords: yield, elemental composition, adaptation, olive varieties

INTRODUCTION

Olive (*Olea europaea L*) is grown over 8.5 million ha in the world with 14, 633, 440 Mg total yield (FAOSTAT, 2005), and it is an important crop for meeting the eating-oil requirement. Olive production has an important share of the

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agricultural economy of Mediterranean countries such as Spain, Italy, Greece, Tunisia, as well as Turkey. Olive is anatomically and physiologically tolerant to water shortages and non selective for soil (Rhizopoulou et al., 1991; Jorba et al., 1985). This enables its cultivation not only in fertile soils but also in non-fertile soils of the Mediterranean region. Low fertility and water deficiency-induced reduction of the photosynthetic rate and shoot growth cause alternate bearing (i.e. alternate years of high and low yield, so called 'on' and 'off' years) and lack of quality along with the reduced yield (Bongi and Palliotti, 1994). As occurs for other fruits, the quantity and quality of olive yield are largely dependent on the ecological environment with optimal input management and genetic characteristics of any variety (Michelakis, 2002; Bignami et al., 1994; Cimato et al., 1990). Olive varieties could be differently influenced by ecological factors and therefore nutrient uptake and effective usage abilities of them can dramatically change. Under these circumstances the macro- or micronutrient requirement of varieties can be different and different varieties may differently respond to nutrient deficiency or toxicity stresses (Demiral, 2004; Chartzoulakis et al., 2002; Loupassaki et al., 2002; Marschner, 1995; Therios and Sakelariadis, 1988; Therios and Misopolinos, 1988). Studies undertaken in Greece and Portugal have demonstrated that elemental composition of leaves, nutrient uptake, and usage ability of different varieties grown under the same ecological conditions were significantly different (Dimassi et al., 1999; Jordao et al., 1999). Thus, understanding the response of olive varieties to different ecological conditions can enable the development of a better fertilization program for balanced nutrition and it can also reduce fertilizer cost and environmental hazards by minimizing leaching losses (Bouma, 1997).

The objectives of this study were to evaluate nutrient uptake and usage efficiency of 21 olive varieties grown under identical ecological conditions. The practical aspect of this study was to relate nutrient uptake and fruit yield to adaptation of cultivars to a different environment.

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MATERIALS AND METHODS

The experiment was conducted at the Kırıkhan Fruit Production Station (36° 18′ E, 36° 27′ N), Hatay, Turkey at 103 m elevation. Hatay is located in the eastern Mediterranean region of Turkey and the region has a typical Mediterranean climate with a hot and dry summer and a moderately cold and rainy winter season. Two Spanish ('Manzanilla' and 'Hojiblanca'), one Italian ('Ascolana'), one Tunisian ('Meski') and 17 Turkish ('Ayvalık', 'Memecik', 'Memeli', 'Domat', İzmir sofralık', 'Sarı yaprak', 'Edincik su', 'Uslu', 'Gemlik', 'Samanlı', 'Sarı ulak', 'Silifke yağlık', 'Kilis yağlık', 'Nizip yağlık', 'Halhalı', 'Savrani', and 'Sarı Haşebi') origin olive varieties were used in this study. The experimental orchard were planted at a spacing of 6 × 6 m as rooted

Table 1
Some chemical and physical properties of the experimental soil

Depth (cm)	Texture Class	Soluble Salts (%)	pH	$CaCO_3$* (g kg^{-1})	K (mg kg^{-1})	P (mg kg^{-1})	OM (g kg^{-1})
0–30	CL	0.020	7.5	254	500	19.6	14.9
30–60	CL	0.035	7.6	272	452	10.9	14.4
60–120	SC	0.040	7.6	348	395	4.19	10.8

*$CaCO_3$ equivalent. CL clay loam, SC sandy clay, OM organic matter

(by means of misting methods) one year old plantlets in 1996 in a complete randomized design with six replicates for each variety.

Particle size distribution was determined by a hydrometer method (Gee and Bauder, 1986). Soil chemical properties were determined following standard procedures (Sparks, 1996), pH and soluble salts in 1:2.5 soil: water suspension, organic matter by potassium dichromate ($K_2Cr_2O_7$) oxidation, calcium carbonate ($CaCO_3$) equivalent by a manometric method, available phosphorus (P) by extraction with 0.5 M sodium bicarbonate ($NaHCO_3$) at pH 8.5 (1 g soil: 20 mL solution), exchangeable potassium (K) by replacing with 1 M ammonium acetate (NH_4CH_3COO) at pH 7.0. Some chemical and physical characteristics of the experimental soil are given in Table 1.

The annual nitrogen (250 g N per tree), phosphorus (250 g P_2O_5 per tree), and potassium (250 g K_2O per tree) requirement of the plants were given 2–3 weeks before the growing season. Plants were irrigated by means of a sub-soil drip irrigation system by considering pan evaporation.

The data of the 2003 and 2004 growing seasons were used in this study. Fruits were hand-harvested at black maturity stage and yield was determined per plant. Middle leaf pairs on the fruitless shoots were sampled from all direction of plants at the beginning of December in both years as suggested by Püskülcü and Aksalman (1988) and Soyergin (1993). Sampled leaves were quickly placed in an ice-box and immediately transferred to the laboratory to remove the contaminants by washing with 0.1% surface reactive detergent and rinsed with de-ionized water. Samples were oven-dried to constant weight at 65–70°C for three days and ground to pass 30 mesh sieves.

Nitrogen content of samples was determined by Kjeldahl digestion and steam distillation (Lees, 1971). For determination of other nutrient elements samples were digested in nitric acid (HNO_3) and perchloric acid ($HClO_4$) (V/V: 4/1) mixture (Kacar, 1972). Phosphorus content of the digests were colorimetrically determined (Shimadzu 1201 model UV/VIS spectrometer, Kyoto, Japan) by means of Barton reagent and K, sodium (Na), calcium (Ca), magnesium (Mg), iron (Fe), copper (Cu), manganese (Mn), and zinc (Zn) contents were determined using inductively coupled plasma (ICP; Varian, Liberty Series II, Varian Inc., Palo Alto, CA, USA).

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The data were subjected to analysis of variance with the SAS package (SAS Institute, Cary, NC, USA). The multiple comparisons of the variety average were performed by Fishers LSD (least significant difference) test ($p < 0.05$). A different letter was given to each different group of varieties (SAS, 1990).

RESULTS AND DISCUSSION

A significant variation among fruit yield of cultivars in both years was observed (Table 2). The 'Gemlik' cultivar produced maximum yield (10,215 g tree^{-1}) in 2003, followed by 'Hojiblanca' (9,528 g tree^{-1}) and 'Memeli' (8,741 g

Table 2
Yield and leaf N, and P concentration of olive varieties in 2003 and 2004

	Yield (g tree^{-1})			N (g kg^{-1})		P (g kg^{-1})	
Varieties	2003	2004	Total	2003	2004	2003	2004
'Manzanilla'	5258 b-d	11559 ab	16817 ab	20.3 a	19.0 a-d	1.6 a-c	1.4 a-c
'Hojiblanca'	9528 a	6643 fg	16171 a-c	18.6 b-d	19.5 a-c	1.6 a-c	1.4 a-c
'Ascolana'	3822 c-e	7551 ef	11373 ef	19.2 a-d	17.5 d-h	1.7 a-c	1.5 ab
'Meski'	4462 b-e	7518 ef	11980 ef	18.7 b-d	16.3 gh	1.7 a-c	1.5 ab
'Ayvalık'	3343 e	8731 c-f	12074 ef	19.7 ab	18.3 b-f	1.6 a-c	1.3 a-c
'Memecik'	4161 b-e	12339 a	16500 a-c	19.1 a-d	18.5 a-e	1.5 bc	1.2 bc
'Memeli'	8741 a	5068 g	13809 b-f	17.9 d	19.6 ab	1.5 bc	1.4 a-c
'Domat'	4475 b-e	9733 b-d	14208 b-e	19.3 a-d	17.9 b-g	1.5 bc	1.3 a-c
'İzmir sofralık'	5308 bc	7917 d-f	13225 c-f	18.6 b-d	17.6 c-h	1.6 a-c	1.3 a-c
'Sarı yaprak'	3523 e	8182 d-f	11705 ef	19.5 a-c	17.7 b-h	1.6 a-c	1.4 a-c
'Edincik su'	3625 de	7465 ef	11090 ef	18.6 b-d	16.5 f-h	1.4 c	1.3 a-c
'Uslu'	4779 b-e	6850 e-g	11629 ef	19.4 a-c	17.9 b-g	1.4 c	1.2 bc
'Gemlik'	10215 a	7419 ef	17634 a	18.7 b-d	20.3 a	2.0 a	1.6 a
'Samanlı'	4216 b-e	8733 c-f	12949 d-f	20.0 ab	19.0 a-d	1.7 a-c	1.5 ab
'Sarı ulak'	5545 b	10345 a-c	15890 a-d	18.2 c-d	16.6 e-h	1.4 c	1.2 bc
'Silifke yağlık'	3489 e	7201 e-g	10690 f	19.5 a-c	16.9 e-h	1.7 a-c	1.4 a-c
'Kilis yağlık'	3543 e	8202 c-f	11745 ef	19.1 a-d	15.8 h	1.7 a-c	1.5 ab
'Nizip yağlık'	4052 b-e	8671 c-f	12723 ef	19.1 a-d	16.0 gh	1.6 a-c	1.3 a-c
'Halhalı'	3709 c-e	8947 c-e	12656 ef	19.6 a-c	16.8 e-h	1.9 ab	1.5 ab
'Savrani'	3583 de	8405 c-f	11988 ef	19.1 a-d	16.7 e-h	1.4 c	1.1 c
'Sarı haşebi'	3765 c-e	6890 e-g	10655 f	19.5 a-c	16.9 e-h	1.6 a-c	1.3 a-c
LSD*	1675	2150	3175	1.5	1.9	0.4	0.3
Deficiency threshold**		—		15		1.0	

*Values are means of six replications. Means separations by Least Significant Difference (LSD) at $P < 0.05$.

**Deficiency threshold values were given according to Fernandez-Escobar et al. (1999).

tree^{-1}) whereas minimum yield was obtained for 'Ayvalık' (3,343 g tree^{-1}) and then 'Silifke yağlık' (3,489 g tree^{-1}), 'Sarı yaprak' (3,523 g tree^{-1}), and 'Kilis yağlık' (3,543 g tree^{-1}), respectively. There was a higher yield in all the cultivars in the 2004 season, except for the three cultivars that gave the highest yield in 2003, 'Hojiblanca ', 'Memeli', and 'Gemlik'. 'Memecik' (12,339 g tree^{-1}), and 'Manzanilla' (11,559 g tree^{-1}) gave the maximum yield and 'Memeli' produced only 5,068 g tree^{-1} olive in 2004.

Leaf N concentration was significantly affected by cultivar and year. Maximum N concentration in the leaves was observed for 'Manzanilla' (20.3 g kg^{-1}), followed by 'Samanlı' and 'Ayvalık' whereas 'Memeli' contained the minimum N (17.9 g kg^{-1}) in 2003 (Table 2). There was a general decrease in 2004 that can be related to increased yield. Many researchers have pointed out that N is transported to fruits, and thus lower leaf N content is observed in "on" years (Toplu, 2000; Fernandez-Escobar and Marin, 1999; Fernandez-Escobar et al., 1999; Jordao et al., 1994; Soyergin, 1993; Fahmy, 1958). Maximum N concentration in 2004 was determined for 'Gemlik' (20.3 g kg^{-1}) and the minimum value for 'Kilis yağlık' (15.8 g kg^{-1}). 'Nizip yağlık', 'Meski' and 'Edincik su' cultivars showed very close values to 'Kilis yağlık' with 16.0, 16.3, and 16.5 g kg^{-1} N concentration, respectively. The leaf N concentration of the cultivars was well above the critical N level (15.0 g kg^{-1}) in both years. Studies in Greece and Portugal showed that leaf N concentrations of various olive varieties were above the critical level (i.e., 18.4–21.5 g kg^{-1}) (Dimassi et al., 1999; Jordao et al., 1999). However, Loupassaki et al. (2002) have reported comparatively higher values for leaf N concentration with a range of 16.8–28.9 g kg^{-1}.

The phosphorus uptake ability of 'Gemlik' was superior to that of other cultivars in both years (2.0 and 1.6 g kg^{-1} in 2003 and 2004). Minimum P concentrations (1.4 g kg^{-1}) were observed for 'Edincik su', 'Uslu', 'Sarı ulak' and 'Savrani 'varieties in 2003, whereas 'Savrani '(1.1 g kg^{-1}), 'Memecik' (1.2 g kg^{-1}), 'Uslu' (1.2 g kg^{-1}) and 'Sarı ulak' (1.2 g kg^{-1}) varieties showed the smallest P concentrations in 2004. A general decrease in P concentration of leaves was recorded as a function of increased yield in 2004. Similarly, Toplu (2000), Fernandez-Escobar et al. (1999), Jordao et al. (1994), and Soyergin (1993) have reported that P contents of leaves are comparatively smaller in "on" years due to its transport from leaves to fruits. The phosphorus levels of the leaves in both years were above the optimum level (1.0 g kg^{-1}), but the P level of Savrani, 'Memecik', 'Uslu' and 'Sarı ulak' varieties in 2004 was close to the deficiency threshold level of leaf P concentration. Leaf P concentration of Greek olives was in the range of 1.3–1.6 g kg^{-1} (Dimassi et al., 1999) while it was 1.2–1.9 g kg^{-1} in Portugal (Jordao et al., 1999). In contrast, Loupassaki et al. (2002) have reported a much higher range of P concentrations (1.7–2.7 g kg^{-1}) for mature leaves.

The potassium concentration of the leaves significantly changed as a function of varieties and years (Table 3). Maximum K content was observed for

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Table 3
K, Ca, Mg, and Na concentration of olive varieties in 2003 and 2004

	K (g kg^{-1})		Ca (g kg^{-1})		Mg (g kg^{-1})		Na (mg kg^{-1})	
Varieties	2003	2004	2003	2004	2003	2004	2003	2004
'Manzanilla'	9.9 ab	8.9 a-d	17.2 f	18.3 f	2.2 a-f	1.7 cd	350 bc	360 b-d
'Hojiblanca'	8.4 c	9.7 ab	18.2 ef	19.0 ef	1.7 f	1.9 a-d	340 bc	380 a-d
'Ascolana'	9.3 a-c	8.5 a-e	18.6 c-f	19.1 ef	1.8 e-f	1.5 d	360 bc	440 a
'Meski'	9.3 a-c	7.6 de	19.8 a-d	20.3 a-e	2.4 a-d	1.9 a-d	370 bc	420 ab
'Ayvalık'	8.9 a-c	8.1 c-e	18.9 b-e	19.2 d-f	2.1 b-f	1.7 cd	350 bc	380 a-d
'Memecik'	8.6 bc	7.6 de	20.3 ab	20.6 a-d	2.3 a-e	1.9 a-d	370 bc	370 a-d
'Memeli'	8.4 c	9.3 a-c	19.1 b-e	19.6 b-f	2.1 b-f	2.2 ab	370 bc	420 ab
'Domat'	10.2 a	8.9 a-d	18.3 d-f	18.7 f	2.2 a-f	1.8 b-d	360 bc	340 cd
'İzmir sofralık'	9.0 a-c	8.8 a-d	18.9 b-e	19.3 c-f	2.0 c-f	1.6 d	360 bc	380 a-d
'Sarı yaprak'	8.6 bc	8.2 b-e	19.0 b-e	19.2 d-f	2.1 b-f	1.7 cd	330 c	360 b-d
'Edincik su'	8.9 a-c	8.3 b-e	18.6 c-f	19.0 ef	2.0 c-f	1.6 d	350 bc	340 cd
'Uslu'	9.3 a-c	8.4 b-e	18.8 b-e	19.6 b-f	2.2 a-f	1.8 b-d	360 bc	360 b-d
'Gemlik'	9.4 a-c	10.0 a	20.0 a-c	20.6 a-d	2.6 ab	2.3 a	360 bc	320 d
'Samanlı'	8.9 a-c	8.2 b-e	18.5 c-f	19.3 c-f	1.9 d-f	1.5 d	360 bc	370 a-d
'Sarı ulak'	8.7 bc	8.2 b-e	20.0 a-c	20.7 a-c	2.5 a-c	2.1 a-c	400 ab	440 a
'Silifke yağlık'	8.4 c	7.7 de	20.2 ab	20.6 a-d	2.4 a-d	1.9 a-d	390 ab	380 a-d
'Kilis yağlık'	8.9 a-c	7.5 de	20.0 a-c	20.8 ab	2.7 a	2.3 a	450 a	430 ab
'Nizip yağlık'	8.7 bc	7.2 e	20.8 a	21.2 a	2.6 ab	2.2 ab	440 a	420 ab
'Halhalı'	9.0 a-c	7.5 de	20.3 ab	20.6 a-d	2.7 a	2.2 ab	360 bc	360 b-d
'Savrani'	9.2 a-c	7.9 c-e	20.8 a	21.1 a	2.6 ab	2.2 ab	370 bc	400 a-c
'Sarı haşebi'	9.4 a-c	8.2 b-e	20.2 ab	20.8 ab	2.4 a-d	1.7 cd	370 bc	420 ab
LSD*	1.4	1.5	0.5	0.4	0.5	0.4	60	70
Deficiency threshold**	4.0		10.0		1.0		—	

*Values are means of six replications. Means separations by Least Significant Difference (LSD) at $P < 0.05$.

**Deficiency threshold values were given according to Fernandez-Escobar et al. (1999).

'Domat' (10.2 g kg^{-1}) whereas 'Hojiblanca ', 'Memeli', and 'Silifke yağlık' showed the same minimum K concentration (8.4 g kg^{-1}) in 2003. There was a general decreasing trend in K concentration in 2004 depending on the yield produced. Toplu (2000), Fernadez-Escobar et al. (1999), Jordao et al. (1994), and Soyergin (1993) have all reported K is negatively associated with yield and increasing yield and increased K transport to fruits results in a decrease in the leaf K content. Potassium concentration ranged between 7.2–10.0 g kg^{-1} in 2004, with the maximum concentration in 'Gemlik' and the minimum K concentration being observed in varieties with high oil content such as 'Nizip yağlık' (7.2 g kg^{-1}), 'Kilis yağlık' and 'Halhalı' (7.5 g kg^{-1}), 'Meski' and 'Memecik' (7.6 g kg^{-1}). Soyergin (1993) reported that commensurate with oil formation in fruits, leaf K content decreases while fruit K content increases. The majority of varieties showed leaf K concentration close to the sufficiency

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threshold (8.0 g kg^{-1}) (Table 3) or below the sufficiency threshold (Fernandez-Escobar et al., 1999), such as in the 'Nizip yağlık', 'Kilis yağlık', 'Halhalı', 'Meski', 'Memecik', 'Silifke yağlık', and 'Savrani 'varieties. Lack of irrigation was reported to inhibit the K uptake and reduced K availability in soils and therefore K deficiency is a common problem of non-irrigated olive orchards (Fernandez-Escobar et al., 1994). Similarly, above 50% of Turkish olives in "on" years were reported to have K deficiency problems in the Marmara region (Soyergin et al., 2002), and Gaziantep (Tekin et al., 1994) and Aydın (Akıllıoğlu (1995) where rain-fed cultivation is practiced despite the very high exchangeable K content of Turkish soils (Aydeniz, 1985). 5.0–9.0 and 5.4–8.3 g kg^{-1} leaf K concentration were reported for Greece (Dimassi et al., 1999) and Portugual (Jordao et al., 1999), respectively. In this study, the K concentrations measured were comparatively higher due to the high exchangeable K content of the experimental soil (395–500 mg kg^{-1}) (Table 1) and irrigation that induces K uptake.

The calcium concentration of the leaves showed significant differences with a range of 17.2–21.2 g kg^{-1}, depending on the variety whereas there was a small difference between the years (Table 3). 'Nizip yağlık', Savrani, 'Sarı Haşebi', 'Halhalı', 'Memecik', 'Sarı ulak', 'Silifke yağlık', and 'Kilis yağlık' had similar Ca concentrations, just above 20 g kg^{-1} in both years. In general, olive varieties grown in the Mediterranean region have high Ca content in their leaves. This can be attributed to adaptation of these local varieties to calcareous soils. Minimum Ca concentration was determined for 'Manzanilla' (17.2 and 18.3 g kg^{-1}), followed by 'Domat' and 'Hojiblanca' (Table 3). All of the varieties showed Ca concentration well above the deficiency threshold (10.0 g kg^{-1}) in both years. Ca nutritional status of olive orchards in different regions of Turkey were well above the sufficiency level (Soyergin et al., 2002; Akıllıoğlu, 1995; Tekin et al., 1994). Similarly, Ca concentration of olive varieties in Greece and Portugual had a range of 14.5–22.0 and 14.5–25.6 g kg^{-1}, respectively. On the other hand, in other work leaf Ca concentration of olive was above 10.0 g kg^{-1} throughout the growing season and the concentration did not change significantly as a function of different growing seasons (Fernandez-Escobar et al., 1999). In fact, the very high carbonate content of soils (254–348 g kg^{-1} in the current experiment) may facilitate Ca uptake of the plants along with the adaptation ability of these varieties to the Mediterranean environment.

Magnesium concentration of the leaves was significantly influenced by variety and growing season (Table 3). Leaf magnesium concentration of 'Kilis yağlık', 'Halhalı', 'Gemlik', 'Nizip yağlık', and 'Savrani 'ranged between 2.2–2.7 g kg^{-1} in both years. Magnesium uptake ability of these varieties was comparatively higher. Minimum values were observed for 'Hojiblanca' (1.7 g kg^{-1}) and 'Ascolana' (1.8 g kg^{-1}) in 2003 and 'Ascolana' and 'Samanlı' (1.5 g kg^{-1}), İzmir 'sofralık' and 'Edincik su' varieties (1.6 g kg^{-1}) in 2004. Despite there being a general decreased trend in the "on" year, Mg concentration of the varieties were above the deficiency threshold (1.0 g kg^{-1}).

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Fernandez-Escobar et al. (1999), however, reported that Mg concentration can be below the deficiency threshold in "on" years. Loupassaki et al. (2002), Dimassi et al. (1999) and Jordao et al. (1999) have all reported that leaf Mg concentration of Greek and Portuguese olives were above 1.0 g kg^{-1}, which are highly similar to our data. Seasonal change of Mg concentration of olive leaves was reported to be in the range of 1.0–2.0 g kg^{-1} (Christos et al., 2005).

There was a significant difference in Na concentration of the leaves depending on the year and variety (Table 3). Higher Na concentration was recorded in the "on" year in 12 of the cultivars. Local varieties such as 'Kilis yağlık' (450 mg kg^{-1}), 'Nizip yağlık' and 'Sarı ulak' (440 mg kg^{-1}), along with the Spanish origin 'Ascolana' (440 mg kg^{-1}) cultivar showed the maximum Na content. Minimum values were recorded for the 'Sarı yaprak' (330 mg kg^{-1}) and 'Gemlik' (320 mg kg^{-1}) cultivars in 2003 and 2004, respectively. Na leaf concentration may change from 100–300 mg kg^{-1} depending on the cultivar (Loupassaki et al., 2002). Demiral (2004) and Chartzoulakis et al (2002) have reported that olive cultivars react differently to Na absorption and transport depending on the Na concentration in the growth media and thus cultivar-induced differences occur in leaf Na content.

The iron concentration of the olive varieties showed a range of 53.6–78.8 mg kg^{-1} and was influenced by variety and growing year (Table 4). Similar values were reported for Greek, Portuguese and Spanish olives (Christos et al., 2005; Jordao et al., 1999; Fernandez-Escobar et al., 1993). Interestingly, there was an increase in Fe content of leaves in the "on" year. On the other hand, there are no certain threshold values for Fe deficiency. As occurs for other species, leaf analysis is not useful for diagnosing Fe deficiency because the inconsistency of leaf Fe levels in separating chlorotic from non-chlorotic leaves (Korcak, 1987). Visual examination of trees is the best method for diagnosing Fe deficiency that is a nutritional problem negatively affecting olive growth in alkaline calcareous soils (Fernandez-Escobar et al., 1993), as in the experimental soil. Olives grow well on calcareous soils, so presumably are adapted to maintain adequate iron despite the antagonism with calcium.

'Memecik' and 'Kilis yağlık' cultivars showed almost the maximum Mn concentration in both years, with an average of 32.92 ± 1.78 mg kg^{-1} although 'Memecik' was higher than 'Kilis yağlık' in 2004, whereas minimum values were recorded for the 'Silifke yağlık', and 'Nizip yağlık' cultivars with an average of 23.1 ± 0.71 mg kg^{-1}. Manganese concentration was inversely related to yield in both years regardless of cultivar. However, the Mn concentration of the leaves was above the deficiency level (20 mg kg^{-1}) in both years. As found in this study, Fernandez –Escobar et al. (1999) reported a smaller Mn concentration in "on" years. The cultivars used in this study had comparatively smaller amounts of Mn than Greek olives (33–72 mg kg^{-1}), but similar to Portuguese olives (14.9–33.7 mg kg^{-1}). Manganese concentration of leaves can show a seasonal change in the range of 14.0–52.8 mg kg^{-1} (Christos et al., 2005).

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Table 4
Fe, Mn, Zn, and Cu concentration of olive varieties in 2003 and 2004

	Fe (mg kg^{-1})		Mn (mg kg^{-1})		Zn (mg kg^{-1})		Cu (mg kg^{-1})	
Varieties	2003	2004	2003	2004	2003	2004	2003	2004
'Manzanilla'	72.5 ab	75.9 ab	33.08 ab	28.2 a-c	21.6 c-f	18.8 e-h	15.2 c-h	16.5 d-g
'Hojiblanca'	71.9 ab	75.8 ab	26.12 cd	28.8 a-c	23.2 a-e	26.0 a-c	17.8 b-e	15.5 fg
'Ascolana'	62.5 a-c	65.0 cd	28.87 bc	26.2 cd	24.9 a-d	23.0 a-e	17.0 c-f	18.7 c-f
'Meski'	63.2 a-c	66.3 cd	28.93 bc	26.5 b-d	15.8 g	14.3 h	16.0 c-g	21.3 a-c
'Ayvalık'	65.5 a-c	68.1 b-d	27.30 cd	25.8 cd	23.7 a-e	20.7 d-g	13.2 f-h	15.7 e-g
'Memecik'	59.6 bc	63.7 d	34.52 a	31.6 a	27.0 a	24.5 a-d	12.5 gh	13.0 g
'Memeli'	53.6 c	65.0 cd	28.10 b-d	31.5 a	21.3 c-f	25.6 a-c	19.5 a-c	18.8 c-f
'Domat'	74.4 a	78.8 a	29.53 a-c	27.7 a-c	20.3 d-g	18.4 e-h	19.0 a-d	20.2 b-d
'İzmir sofralık'	67.2 a-c	70.8 a-d	26.25 cd	24.9 cd	23.4 a-e	22.7 a-e	13.5 e-h	15.5 fg
'Sarı yaprak'	63.1 a-c	71.7 a-d	27.00 cd	25.2 cd	22.9 a-e	22.0 b-f	15.0 d-h	20.0 b-e
'Edincik su'	67.2 a-c	73.0 a-c	28.47 b-d	27.5 a-c	22.1 b-e	21.8 b-f	15.0 d-h	16.2 d-g
'Uslu'	53.9 c	64.5 cd	26.37 cd	25.1 cd	21.8 b-e	22.2 b-e	21.7 ab	23.3 ab
'Gemlik'	66.8 a-c	73.3 a-c	28.83 bc	27.5 a-c	26.3 ab	27.2 a	22.5 a	18.7 c-f
'Samanlı'	63.9 a-c	67.3 b-d	28.80 bc	25.5 cd	24.5 a-d	22.4 a-e	12.5 gh	15.5 fg
'Sarı ulak'	61.3 a-c	65.8 cd	26.97 cd	24.1 cd	21.9 b-e	21.3 c-f	11.0 h	13.5 g
'Silifke yağlık'	59.0 bc	63.1 d	23.62 d	22.8 d	25.4 a-c	24.8 a-d	12.3 gh	16.3 d-g
'Kilis yağlık'	62.2 a-c	65.7 cd	34.37 a	31.2 ab	24.3 a-d	26.6 ab	16.5 c-g	24.3 ab
'Nizip yağlık'	61.4 a-c	65.5 c-d	23.77 d	22.3 d	17.1 fg	16.0 gh	17.5 b-f	23.3 ab
'Halhalı'	62.7 a-c	66.8 b-d	27.08 cd	25.3 cd	19.1 e-g	17.2 f-h	19.2 a-d	25.0 a
'Savrani'	63.6 a-c	66.9 b-d	28.53 b-d	25.3 cd	25.2 a-c	23.7 a-d	17.7 b-e	23.8 ab
'Sarı haşebi'	63.8 a-c	71.7a-d	27.3 cd	25.2 cd	22.9 a-e	18.5 e-h	17.5 b-f	23.3 ab
LSD*	14.52	9.40	5.00	4.73	4.64	4.87	4.34	4.44
Deficiency threshold**	—		20.0		10.0		4.0	

*Values are means of six replications. Means separations by Least Significant Difference (LSD) at $P < 0.05$.

**Deficiency threshold values were given according to Fernandez-Escobar et al. (1999).

Zinc uptake ability of varieties was significantly different and dependent on the year. The 'Memecik', 'Gemlik', and 'Kilis yağlık' varieties had the highest Zn in leaves (26.8 $\pm$ 0.40 mg kg^{-1}); whereas 'Meski' and 'Nizip yağlık' varieties showed the lowest leaf Zn concentration with average values of 15.1 $\pm$ 0.74 and 16.5 $\pm$ 0.50 mg kg^{-1}, respectively (Table 4). Zinc concentration was slightly reduced by the increased yield in 2004. However, Zn concentration of all varieties was well above the deficiency threshold level (10 mg kg^{-1}). Fernadez-Escobar et al. (1999) reported only small fluctuation in the Zn concentration of mature leaves in different years whereas an apparent seasonal fluctuation in the Zn concentration of leaves between 12.4 and 30.2 mg kg^{-1} was reported (Christos et al., 2005). Olive cultivars in Greece were reported to contain 10–16 mg Zn kg^{-1} (Dimassi et al., 1999), but in Portugual it was somehow much higher, with a range of 16.9–30.3 mg Zn kg^{-1} (Jordao et al., 1999).

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The average leaf Cu concentration of the olive varieties were 16.3 ± 3.1 and 19.0 ± 3.8 mg kg^{-1} in the 2003 and 2004 growing seasons. 'Gemlik' (22.5 mg kg^{-1}) and 'Uslu' (21.7 mg kg^{-1}) in 2003, and 'Halhalı' (25.0 mg kg^{-1}), 'Savrani '(23.8 mg kg^{-1}), 'Uslu' and 'Nizip yağlık' (23.3 mg kg^{-1}) in 2004 showed the highest Cu concentration whereas 'Sarı ulak' (11.0 and 13.5 mg kg^{-1}) showed the minimum values in both growing seasons, except for 'Memecik' (13.0 mg kg^{-1}) in 2004. Interestingly there was an increase in Cu leaf concentration in the "on" year in 18 of 21 cultivars; only 'Hojiblanca', 'Memeli' and 'Gemlik' had lower concentrations, and these were the three highest yielding cultivars in the previous season. Copper absorption of varieties was adequate and leaf Cu contents were well above the deficiency threshold (4 mg kg^{-1}). The reason for such high Cu content could be related to the Cu-containing pesticide used against fungi. Fernandez-Escobar et al. (1999) have reported that Cu concentration in the leaf can be as high as 80 mg kg^{-1} at certain growth stages.

Overall evaluation of nutritional status and yield was delineated by means of bivariate correlation coefficients (Table 5). All nutrient elements were well above the deficiency threshold. Total yield over the alternate bearing cycle of an 'on' and 'off' year positively correlated with N ($r = 0.642^{**}$) and K ($r = 0.551^{*}$) concentration of leaf in 2004 whereas negatively correlated to Cu ($r = -474^{*}$) concentration (Table 5). There were no strong negative relationships between the elements and yield but nitrogen uptake in the "off" year (Table 5) was negatively related to yield ($r = -0.530^{*}$), probably induced by insufficient fruit set. A positive significant correlation between yield and Cu uptake ($r = 0.444^{*}$) was observed in the "off" year. Despite the fact that there was no visually and analytically determined Cu deficiency in any variety, higher Cu absorption increased fruit set. Interestingly, Cu concentrations of the leaves were higher in the "on" year (Table 4). Copper deficiency affects the reproductive phase more than the vegetative phase by influencing anther development and pollen sterility in higher plants. Therefore, reduced fruit set may be related to both reduced pollen fertility and failure of the stomiato rupture, as pointed out by Dell (1981).

Bivariate correlation coefficients between leaf nutrient concentrations are given in Table 5. The concentration of Ca in leaves was positively correlated with Mg and Na (only in 2003) concentrations, while it negatively affected Fe uptake. Calcium, Mg, and Na ions in exchange sites are common cations of arid region soils (Brady, 1990) as in the experimental soil. Therefore, such positive significant correlation coefficients between Ca, Mg, and Na uptake are expected. Similarly, an antagonistic effect between Fe and Ca is a well known fact (Marschner, 1995) which was confirmed by negative significant correlation coefficients ($r = -0.480^{*}$ and 0.571^{*}) for the olive varieties. Since the experimental soil contains very high exchangeable-K (Table 1) a strong positive correlation was observed between K and Fe uptake ($r = 0.51^{*}$ in 2003

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Table 5
Bivariate correlation coefficients between parameters for 2003 (a) and 2004 (b)

Parameters	Total yield	Yield	N	P	K	Ca	Mg	Fe	Mn	Zn	Cu	Na
Total yield		0.686**a	−0.191a	0.123a	0.100a	−0.200a	−0.008a	0.352a	0.348a	0.159a	0.063a	−0.134a
Yield	0.459*b		−0.530*a	0.223a	−0.110a	−0.192a	−0.176a	0.118a	−0.056a	0.097a	0.444*a	−0.197a
N	0.642**b	−0.052b		0.223a	0.380a	−0.231a	0.007a	0.226a	0.148a	0.101a	−0.131a	−0.168a
P	0.067b	−0.269b	0.250b		0.066a	0.150a	0.243a	0.137a	0.000a	0.050a	0.244a	0.022a
K	0.551*b	−0.301b	0.800**b	0.224b		−0.323a	0.099a	0.510*a	0.328a	−0.178a	0.364a	−0.185a
Ca	−0.125b	−0.016b	−0.470*b	−0.128b	−0.521*b		0.774**a	−0.480*a	−0.176a	0.000a	0.032a	0.578**a
Mg	0.269b	−0.063b	−0.114b	0.048b	−0.089b	0.694**b		−0.241a	0.089a	−0.176a	0.191a	0.618**a
Fe	0.360b	0.086b	0.351b	0.099b	0.609**b	−0.571**b	−0.253b		0.178a	−0.028a	−0.042a	−0.329a
Mn	0.405b	0.073b	0.411b	0.174b	0.322b	−0.218b	0.173b	0.149b		0.279a	−0.062a	0.058a
Zn	0.237b	−0.245b	0.450*b	0.078b	0.445*b	−0.002b	0.178b	−0.098b	0.438*b		−0.198a	−0.155a
Cu	−0.474*b	−0.319b	−0.451*b	0.089b	−0.328b	0.413b	0.418b	−0.117b	−0.151b	−0.318b		−0.073a
Na	−0.294b	−0.163b	−0.472*b	−0.087b	−0.375b	0.390b	0.168b	−0.541*b	−0.074b	−0.108b	0.170b	

*Correlation is significant at the 0.05 level (2-tailed) and **at the 0.01 level (2-tailed).

and 0.609** in 2004). Potassium fertilization is often practiced to stimulate Fe uptake (Marschner, 1995).

In the "on" year Ca uptake negatively affected both N and K concentration in the leaves, in addition to Fe. An antagonism was reported between Ca and K in K poor soils (Günes et al., 2000). Zinc concentration showed significant correlation coefficients with N, K and Mn concentrations of the leaves. On the other hand, N concentration showed significant negative correlations with Ca, Cu, and Na uptake.

It can be concluded that nutrient uptake ability and usage efficiency of varieties are different underground drip irrigation and standard fertilization. Better yield performance, along with the nutrient uptake, could be an indication of adaptation of a cultivar to a specific ecological environment and growing conditions. Leaf nutrient contents of cultivars in "on" years is usually decreased due to their transport to fruits, but the leaf concentration of Fe and Cu slightly increased and Zn, Na and Ca did not change significantly.

'Gemlik', 'Manzanilla', 'Memecik', 'Hojiblanca', 'Sarı ulak', and 'Domat' cultivars showed better yield performance than the other cultivars. Therefore, these cultivars should be suggested to farmers for new orchard foundation in the region.

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