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Research Article

Nutrient Dynamics of *Olea europaea* L. Growing on Soils Derived from Two Different Parent Materials in the Eastern Mediterranean Region (Turkey)

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Abstract: *Olea europaea* L. (olive tree, *Oleaceae*), an important tree in the Mediterranean region, adds considerable amounts of leaf litters to soils, which may help in maintaining soil productivity. The aim of this study was to investigate temporal changes in the carbon (C), nitrogen (N), phosphorus (P) and potassium (K) contents of leaves, shoots, leaf litters and soils together with the amounts of leaf litters and humic and fulvic acids in the soils of olive trees growing on both marl and conglomerate parent materials in the Eastern Mediterranean region (Turkey). The element contents of leaf, shoot, leaf litter and soil samples and the amounts of olive leaf litters were compared between the 2 different parent materials at each sampling time. There were no statistical differences between the 2 parent materials. The results showed that olive trees can adapt to their environment very well without discriminating between parent materials. There were significant differences among the sampling times in the C and N contents of the leaf litters and available P content of the soils. This can be explained by the rapid decomposition of olive leaf litters during the sampling time intervals. Available P contents of the soils with marl and conglomerate parent materials may have been decreased by adsorption reactions over time.

Key Words: *Olea europaea*, Parent material, Litter, C, N, P, K, Humic and fulvic acids

Doğu Akdeniz Bölgesinde (Türkiye) İki Farklı Anamateryalden Oluşmuş Topraklarda Yetişen *Olea europaea* L.'nın Besin Dinamikleri

Özet: *Olea europaea* L. (zeytin ağacı, *Oleaceae*) Akdeniz Bölgesinde önemli bir ağaç olup toprağa önemli miktarda yaprak döküntüsü ilave eder ki bu da toprak verimliliğinin sürdürülmesine katkılar sağlayabilir. Bu çalışmanın amacı Doğu Akdeniz (Türkiye) Bölgesinde hem marn hem de konglomera anamateryallerinde yetişen zeytin ağacının topraklarında humik ve fulvik asitlerinin ve yaprak döküntülerinin miktarları ile birlikte yaprak, sürgün, yaprak döküntüsü ve topraklarının karbon (C), azot (N), fosfor (P) ve potasyum (K) içeriklerinin zamana bağlı değişimlerini incelemektir. Zeytinin yaprak, sürgün, yaprak döküntüsü, toprak örneklerinin element içerikleri ve yaprak döküntüsünün miktarları her bir örnekleme zamanında iki farklı anamateryal arasında kıyaslanmıştır. İki anamateryal arasında istatistiksel farklılıklar bulunamamıştır. Sonuçlar zeytinin anamateryal farkı ayırt etmeksizin yaşadığı çevreye çok iyi adapte olabildiğini göstermiştir. Toprakların yarayışlı P içeriği ve yaprak döküntüsünün C ve N içeriklerinde örnekleme zamanları arasında anlamlı farklılıklar bulunmuştur. Bu durum örnekleme zaman aralıkları boyunca zeytin yaprak döküntüsünün hızlı ayrışmasıyla açıklanabilir. Marn ve konglomera anamateryalli toprakların yarayışlı P içerikleri zaman içerisinde adsorpsiyon reaksiyonları ile azalmış olabilir.

Anahtar Sözcükler: *Olea europaea*, Anamateryal, Döküntü, C, N, P, K, Humik ve fulvik asitler

Introduction

Falling tree leaves comprise an important source of organic matter in soils. In the Mediterranean region, olive trees add considerable amounts of leaf litters to the soils that on decomposition are potential sources of nutrients in the ecosystems. The balance between nutrient production and consumption can be maintained if nutrient inputs and outputs are known (Çepel et al., 1988). Litterfall including 90% leaf (Stevenson, 1982) is the most important process for returning nutrients to the soil in ecosystems. This return may increase depending on the amount of annual litterfall (Gray & Schlesinger, 1981).

Organic matter content depends upon the textural properties of the soils (Akalan, 1983). The fixation of humic substances in the form of organo-mineral complexes serves to preserve organic matter. Thus heavy-textured soils have higher organic matter content than loamy soils, which in turn have higher organic matter contents than sandy soils (Stevenson, 1982). Parent material, topography, vegetation, time and climate have long been recognised as factors affecting the formation and composition of the soils (Stevenson, 1982; Akalan, 1983; Özbek et al., 1995; Trettin et al., 1999). Parent material also constitutes the primary source of plant nutrients. Thus, the same species growing on 2 different parent materials may have different nutrient and humus contents. Accordingly, it is important to choose plants that can show the parent material difference best. Species that have a large adaptability and spread and especially chose growing naturally in the research area should be chosen.

There are few studies about annual variations in the nutrients contents of leaves, shoots, leaf litters and soils of the plants in Turkey (Dikmelik, 1994). There has been no study on the effect of parent material on soil properties and plants, besides organic matter humification by the determination of humic and fulvic acid amounts in the soils.

The humic and fulvic acid amounts in soils with different parent materials were for the first time determined in this study in the Eastern Mediterranean region, Turkey, because this topic has gained attention recently in Turkey.

Our research was planned to investigate temporal changes in the C, N, P and K contents of leaves, shoots, leaf litters and soils together with the amounts of leaf litters, humic and fulvic acids in *Olea europaea* L. (olive tree, *Oleaceae*) soils derived from 2 different parent materials (marl and conglomerate) in the Eastern Mediterranean region, Turkey.

Study Area

This study was conducted at 2 sites with 2 different parent materials at Çukurova University campus in Adana, characterised by the semi-arid Mediterranean climate (mean annual precipitation of 663 mm, mean annual temperature of 18.7 ºC) and located in the Eastern Mediterranean region of Turkey. The precipitation and temperature data of Adana are based on a 50-year period (Meteoroloji Bülteni, 2001). One of the sites had marl parent material at Çukurova Süleyman Demirel Arboretum (altitude 105 m; 37º0.4′N, 35º21′E), 3 km north-east of the campus. The other had conglomerate parent material at the campus (altitude 135 m; 37º0.3′N, 35º20′E) of Çukurova University. Marl and conglomerate parent materials were chosen as they dominate in this region. The localities of plant and soil samples in both sites were determined by Garmin mark GPS III software, version 2.0.

Materials and Methods

Olive trees of about the same size were selected for growing on both parent materials as they are characteristic Mediterranean species. They had been planted 25 years previously and had grown up naturally without human impact. Leaves, shoots, leaf litters and soils of this plant were used as the study materials. All samples were taken 4 times between September 1999 and 2000 (6 September 1999, 5 March 2000, 6 June 2000 and 11 September 2000) from both sites. Leaf samples (100-150 leaves) were collected from the middle part of the shoot corresponding to each growth period and then mixed. This sampling was repeated for each leaf, shoot and leaf litter samples of 5 olive trees. The shoots from which the leaves were taken were also sampled and mixed. These samples were oven dried at 70 ºC to constant weight and ground. Leaf litter sampling was performed by locating a template (25 x 25 cm, converted to kg/m^2) randomly on the litter and then carefully collecting all dead material within the inner area of the template. This was sorted from the other plant parts such as wood and miscellaneous materials, which were in very small amounts in the litter. This was also oven dried at 70 ºC to constant weight and ground. A superficial soil sample (0-10 cm) from each of the 5 olive trees was collected and sieved through a 2 mm mesh sieve after removing recognisable plant debris.

The soil texture was determined by a Bouyoucos hydrometer (Bouyoucos, 1951), and field capacity water (%) by a vacuum pump with 1/3 atmospheric pressure (Demiralay, 1993). The pH was measured in a 1:2.5 soil-to-water suspension with a pH meter (Jackson, 1958). The lime content (%) was determined by Scheibler calcimeter (Allison & Moodie, 1965) and cation exchange capacity (meq/100 g) by 1 N CH_3COONH_4 by atomic absorption spectrophotometry (Philips, PU 9100X model atomic absorption spectrophotometer). The organic carbon content (%) of soil and plant samples was determined by the Walkley & Black (1934) method;

organic matter was obtained from the carbon values (%) multiplied by 1.724 (Duchaufour, 1970). The organic nitrogen content (%) was determined by the Kjeldahl method (Duchaufour, 1970). Phosphorus (P) and potassium (K) concentrations (%) were determined in leaves, shoots and leaf litter by the HNO_3-$HClO_4$-H_2SO_4 mix method (Jackson, 1958). Available P (mg/kg) and K (meq K/100 g) for plants in the soil samples were determined with 0.5 M $NaHCO_3$ (Olsen et al., 1954) and boiling nitric acid extraction (Özbek et al., 1995), respectively. P concentration was measured by Unicam UV/Vis spectrophotometer and K concentration by Corning 410 flame photometer. The ratio of humus forms in the soil was determined by 0.5 N NaOH extraction (Scheffer & Ulrich, 1960).

Data were analysed by univariate analysis of variance for each nutrient and characteristic of the 2 different parent materials. Repeated measures (general linear model) were applied for temporal changes (times x parent materials). Difference levels among means were analysed with Tukey's test (Kleinbaum et al., 1998). The mean of 5 samples was used for each leaf, shoot, leaf litter and soil sample for comparisons. All statistical analyses were carried out using SPSS (version 11.5, 2002).

Results and Discussion

Soils with marl and conglomerate parent materials were classified as Entisols and Alfisols, respectively (Soil Survey Staff, 1998). These soils were light brownish grey (10 YR 6/2) and dark red (2.5 YR 3/6), respectively. The physical and chemical properties of the soils with marl (loam textured) and conglomerate (sandy loam textured) are given in Table 1.

While the clay and silt ratios (%) of soil with conglomerate were lower than these of soil with marl, the sand ratio (%) of soil with conglomerate was higher than that of soil with marl ($P < 0.001$ for all of them). Field capacities of these 2 soils varied between 27.9% and 33.1% ($P < 0.01$). The pH of soil with marl (pH 7.57) was statistically different from that of soil with conglomerate (pH 7.32, $P < 0.01$). The $CaCO_3$ ratio (%) of soil with marl was significantly higher than that of soil with conglomerate ($P < 0.001$). The cation exchange capacity (meq/100 g) of soil with marl was lower than

Table 1. Physical and chemical properties of the olive soils from 2 different parent materials. +Mean ± standard error; n = 5. *, ** Significant at the 0.01 and 0.001 probability levels, respectively.

Characteristic	Parent material	
	Marl	Conglomerate
Texture type	Loam (L)	Sandy Loam (SL)
Clay [< 0.002 mm, (%)]	10.3 ± 0.36+	7.00 ± 0.39**
Silt [0.02-0.002 mm, (%)]	42.2 ± 0.70	21.4 ± 1.45**
Sand [2-0.02 mm, (%)]	47.5 ± 0.50	71.7 ± 1.62**
Field capacity (%)	33.1 ± 1.50	27.9 ± 0.41*
pH	7.57 ± 0.03	7.32 ± 0.07*
$CaCO_3$ (%)	23.2 ± 0.87	1.20 ± 0.21**
Cation exchange capacity (meq/100 g)	31.5 ± 2.24	49.3 ± 1.42**
C (%)	2.33 ± 0.51	2.96 ± 0.18
N (%)	0.19 ± 0.03	0.26 ± 0.02
C/N ratio	11.7 ± 0.79	11.4 ± 0.43
Organic matter (%)	4.02 ± 0.87+	5.10 ± 0.32
Humic acid / organic matter (%)	14.3 ± 2.01	9.01 ± 1.10
Fulvic acid / organic matter (%)	63.7 ± 6.95	27.9 ± 2.91**
Humic acid / fulvic acid	0.22 ± 0.02	0.34 ± 0.06

that of soil with conglomerate ($P < 0.001$). Soil organic carbon and nitrogen contents varied from 2.33% to 2.96% and 0.19% to 0.26%, respectively. C/N ratios in marl and conglomerate soils were 11.7 and 11.4, respectively.

The proportion of organic matter, and the ratios of humic acid to organic matter and of humic acid to fulvic acid of the olive soils did not differ significantly between the 2 parent materials. However, the ratio of fulvic acid to organic matter of soil with marl was higher than that of soil with conglomerate ($P < 0.001$, Table 1). This result showed that fulvic acid was highly associated with the finest soil particles in the soils derived from marl parent material. Stevenson (1982) emphasised that a high correlation exists between the organic matter and clay contents of many soils. Oades et al. (1987) and Baldock et al. (1992) mentioned that aliphatic compounds, which constitute the basic component of the recalcitrant organic matter, were strictly associated with the finest (<2 µm) soil particles.

Amounts (kg/m^2) of olive leaf litter did not differ significantly between the parent materials (Table 2).

There were no significant differences between the 2 parent materials when the C, N, P and K contents of the olive leaves, shoots and leaf litters were compared at each sampling time (Tables 3-5).

Zas & Serrada (2003) reported no significant differences in the P foliar concentrations of *Pinus radiata* D.Don between different parent materials. N, P and K contents of olive leaves were similar to the data of different studies (Jones et al., 1991; Dikmelik, 1994; Dimassi, 1999; Fernández-Escobar et al., 1999). In fact, the olive is a Mediterranean plant that grows well in clay soils with excess lime and organic matter, but it is also a tolerant plant that can survive and can be cultivated in soils with low nutrient contents (Çeçen, 1968; Dikmelik, 1994; Dimossi, 1999). Because of their wide spread in the Mediterranean basin, olive trees are related to this region (Polunin & Huxley, 1987; Makhzoumi, 1997). Over 9 million hectares of the world's surface is cultivated with olives, 98% of which are grown in the Mediterranean basin (Araüés et al., 2004). The amounts and ratios of the nutrients in olive leaves can change depending on variety differences, more or less pruning, and ecological properties, especially soil structure and depth, and climate (Marschner, 1995). The nutrient contents of olive leaves show that this plant can adapt to its environment very well without discriminating between parent materials.

There were also no significant differences in respect of C, N, P and K contents between soils derived from marl and conglomerate (Table 6).

Yavitt (2000) mentioned that there were no parent material differences in concentrations of N, P and S among litter and soil across 3 very different parent

Table 2. Amounts of the olive leaf litters (kg/m^2) in 2 different parent materials. $^+$Mean ± standard error; n = 5.

Sampling Time	Parent material	
	Marl	Conglomerate
September 1999	0.50 ± 0.08$^+$	0.69 ± 0.14
March 2000	0.82 ± 0.21	0.88 ± 0.09
June 2000	0.54 ± 0.10	0.94 ± 0.23
September 2000	0.88 ± 0.38	0.75 ± 0.09

Table 3. Influence of parent material on nutrient concentration in the olive leaves. $^+$Mean ± standard error; n = 5.

Elements	Sampling Time	Parent material	
		Marl	Conglomerate
C (%)	September 1999	35.4 ± 1.15$^+$	46.7 ± 3.55
	March 2000	45.0 ± 2.52	38.3 ± 3.65
	June 2000	44.5 ± 2.32	43.3 ± 1.07
	September 2000	47.6 ± 1.75	45.9 ± 1.60
N (%)	September 1999	1.33 ± 0.17	1.34 ± 0.10
	March 2000	1.55 ± 0.14	1.69 ± 0.09
	June 2000	1.77 ± 0.12	1.69 ± 0.09
	September 2000	1.16 ± 0.04	1.15 ± 0.03
P (%)	September 1999	0.06 ± 0.005	0.08 ± 0.006
	March 2000	0.10 ± 0.011	0.09 ± 0.005
	June 2000	0.10 ± 0.005	0.10 ± 0.005
	September 2000	0.07 ± 0.007	0.08 ± 0.003
K (%)	September 1999	0.89 ± 0.05	0.84 ± 0.05
	March 2000	0.88 ± 0.04	0.76 ± 0.07
	June 2000	0.95 ± 0.06	1.06 ± 0.06
	September 2000	0.91 ± 0.08	0.80 ± 0.05

Table 4. Influence of parent material on nutrient concentration in the olive shoots. +Mean ± standard error; n = 5.

Elements	Sampling Time	Parent material	
		Marl	Conglomerate
C (%)	September 1999	35.7 ± 3.65+	49.4 ± 1.97
	March 2000	43.3 ± 3.60	47.7 ± 2.24
	June 2000	45.7 ± 3.16	42.3 ± 1.67
	September 2000	42.7 ± 1.42	48.3 ± 3.32
N (%)	September 1999	0.63 ± 0.05	0.62 ± 0.04
	March 2000	0.65 ± 0.03	0.85 ± 0.09
	June 2000	0.80 ± 0.05	0.81 ± 0.03
	September 2000	0.75 ± 0.02	0.64 ± 0.04
P (%)	September 1999	0.05 ± 0.005	0.10 ± 0.014
	March 2000	0.06 ± 0.010	0.09 ± 0.014
	June 2000	0.07 ± 0.007	0.10 ± 0.010
	September 2000	0.05 ± 0.005	0.10 ± 0.015
K (%)	September 1999	1.05 ± 0.09	1.07 ± 0.05
	March 2000	0.88 ± 0.14	0.83 ± 0.05
	June 2000	0.83 ± 0.13	0.94 ± 0.11
	September 2000	0.95 ± 0.12	1.05 ± 0.07

Table 5. Influence of parent material on nutrient concentration in the olive leaf litters. +Mean ± standard error; n = 5.

Elements	Sampling Time	Parent material	
		Marl	Conglomerate
C (%)	September 1999	30.0 ± 2.43+	37.3 ± 3.17
	March 2000	34.2 ± 1.57	35.8 ± 2.36
	June 2000	37.2 ± 1.47	33.6 ± 1.06
	September 2000	46.9 ± 1.04	46.4 ± 3.26
N (%)	September 1999	1.12 ± 0.05	1.15 ± 0.05
	March 2000	1.09 ± 0.12	1.36 ± 0.06
	June 2000	1.33 ± 0.10	1.31 ± 0.11
	September 2000	0.87 ± 0.04	1.01 ± 0.08
P (%)	September 1999	0.05 ± 0.004	0.06 ± 0.005
	March 2000	0.07 ± 0.009	0.08 ± 0.007
	June 2000	0.06 ± 0.007	0.07 ± 0.002
	September 2000	0.04 ± 0.003	0.05 ± 0.003
K (%)	September 1999	0.27 ± 0.03	0.40 ± 0.04
	March 2000	0.21 ± 0.02	0.24 ± 0.02
	June 2000	0.20 ± 0.03	0.31 ± 0.03
	September 2000	0.36 ± 0.07	0.44 ± 0.06

Table 6. Influence of parent material on nutrient concentration in the olive soils. +Mean ± standard error; n = 5.

Elements	Sampling Time	Parent material	
		Marl	Conglomerate
C (%)	September 1999	2.05 ± 0.32+	2.99 ± 0.35
	March 2000	2.46 ± 0.47	3.26 ± 0.38
	June 2000	1.99 ± 0.25	3.31 ± 0.66
	September 2000	2.33 ± 0.51	2.96 ± 0.18
N (%)	September 1999	0.19 ± 0.03	0.27 ± 0.02
	March 2000	0.25 ± 0.03	0.33 ± 0.02
	June 2000	0.20 ± 0.02	0.28 ± 0.03
	September 2000	0.19 ± 0.03	0.26 ± 0.01
Available P (mg/kg)	September 1999	8.83 ± 0.33	17.9 ± 2.30
	March 2000	10.5 ± 1.91	16.8 ± 3.10
	June 2000	6.76 ± 1.26	14.0 ± 3.67
	September 2000	6.96 ± 1.20	12.3 ± 1.50
Available K (meq/100g)	September 1999	3.09 ± 0.24	3.82 ± 0.33
	March 2000	3.05 ± 0.23	3.46 ± 0.36
	June 2000	3.05 ± 0.22	3.89 ± 0.56
	September 2000	3.40 ± 0.37	4.18 ± 0.42

Table 7. Results of the general linear model for repeated measures of elemental contents of different parts of the olive trees sampled between September 1999 and 2000. Effects of different sampling times and parent materials.

Source of variation			df	F	P
Leaf	C	Times	1	4.054	0.079
		Times x parent materials	1	3.102	0.116
	N	Times	1	2.294	0.168
		Times x parent materials	1	0.236	0.640
	P	Times	1	0.634	0.449
		Times x parent materials	1	1.317	0.284
	K	Times	1	0.635	0.449
		Times x parent materials	1	0.006	0.942
Shoot	C	Times	1	0.896	0.372
		Times x parent materials	1	4.174	0.075
	N	Times	1	3.159	0.113
		Times x parent materials	1	2.399	0.160
	P	Times	1	0.584	0.467
		Times x parent materials	1	0.129	0.729
	K	Times	1	0.534	0.486
		Times x parent materials	1	1.046	0.336
Leaf litter	C	Times	1	35.269	<0.001
		Times x parent materials	1	4.676	0.063
	N	Times	1	8.771	0.018
		Times x parent materials	1	0.001	0.973
	P	Times	1	4.864	0.058
		Times x parent materials	1	0.083	0.780
	K	Times	1	4.357	0.070
		Times x parent materials	1	0.100	0.760
Soil	C	Times	1	0.021	0.887
		Times x parent materials	1	0.045	0.838
	N	Times	1	0.758	0.409
		Times x parent materials	1	0.109	0.749
	P	Times	1	8.108	0.022
		Times x parent materials	1	1.018	0.343
	K	Times	1	1.110	0.323
		Times x parent materials	1	0.067	0.802
Amounts of olive leaf litter		Times	1	1.156	0.314
		Times x parent materials	1	0.342	0.575

materials (andesite, limestone and conglomerate) on Barro Colorado Island. In contrast, Klemmedson (1994) reported that amounts of C_{org}, N, P and K were all significantly greater in soils derived from basalt than those derived from limestone. These findings showed that differences in C, N, P and K contents of soils can change depending on different parent materials.

Litter nutrient concentration is sensitive to soil supply and hence provides a more direct assessment of the interactions between long-term changes in soil chemical properties and nutrient availability (Trettin et al., 1999). In our study, significant differences were found among the sampling times in C ($P < 0.001$) and N contents ($P = 0.018$) of the olive leaf litters in both parent materials (Table 7).

While the C content of leaf litter was highest in September 2000, the N content was lowest in the same month. The C and N contents of olive leaf litter were similar to the C and N contents of olive leaves depending on the sampling times. While the C contents of leaves and leaf litters of olive trees increased from September 1999 to September 2000, N contents of both parts decreased in this interval. However, there were no significant differences among the sampling times in the C and N contents of olive leaves. Because of the quick decomposition of leaf litter thus resulting in fast and effective nutrient cycling (Luizáo et al., 2004), the C and N contents of leaf litter can vary among sampling times. It can also be explained by biomass production, organic matter decomposition and soil nutrient supply. Changes in forest floor nutrient pool size are a direct function of forest floor mass and nutrient concentration; those factors in turn are controlled by biomass production, organic matter decomposition, soil nutrient supply and nutrient retention. While periodic measurements of pool size do not allow an assessment of those causative factors, they do enable the assessment of the temporal changes and relationship with other soil and site variables (Trettin et al., 1999). Haines & Cleveland (1981) reported significant seasonal variation in soil organic matter for several forest types.

There were also significant differences among the sampling times in the available P content ($P = 0.022$) of the olive soils derived from marl and conglomerate parent materials (Table 7). Available P content of the soils decreased from September 1999 to September 2000 in both parent materials, although the leaf litter had a greater quantity of P. The most probable explanation for the decline in available P of the soil is adsorption onto Fe and Al hydrous oxides (Trettin et al., 1999). Sanchez (1976) and Hue (1991) also reported that P is the most limiting for crop production in large parts of the tropics and is a primary consequence of adsorption and precipitation reactions with sesquioxides rather than low amounts of total P. In our study, there were no significant differences between the sampling times and parent materials for available P content. Thus, available P content of the soils with marl and conglomerate parent materials may be decreased by adsorption reactions over time.

In conclusion, the results of this study show almost no variation in C, N, P and K contents of leaves, shoots, leaf litters and soils of olive trees growing on soils with marl and conglomerate parent materials in the Eastern Mediterranean region of Turkey. This does not mean that the sites derived from marl and conglomerate have exactly the same rates of nutrient cycling.

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