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Research Article

Nutrient Contents of *Pinus brutia* Ten. (*Pinaceae*) and *Pistacia terebinthus* L. (*Anacardiaceae*) Growing on Marl and Conglomerate Substrata in the Eastern Mediterranean

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Abstract: The eastern Mediterranean region is one of the main areas of the Mediterranean vegetation containing Calabrian cluster pine (*Pinus brutia* Ten., *Pinaceae*) forests and terebinth (*Pistacia terebinthus* L., *Anacardiaceae*) communities. This study was carried out with the leaves, shoots, leaf litters, and soils of Calabrian cluster pine and terebinth growing on both marl and conglomerate substrata in the eastern Mediterranean region (Turkey) to determine average C, N, P and K contents, and the amounts of humic and fulvic acid in these plant soils. The average element contents of leaf, shoot, leaf litter and soil samples of both plants from the 2 different substrata were compared and exhibited only a few relatively subtle differences. The average C and N contents in the terebinth soils derived from conglomerate substratum were significantly higher than those in soils derived from marl substratum. Yet, it did not differ in the Calabrian cluster pine. While the average P and K concentrations of terebinth leaves and shoots varied significantly between the substrata, they did not vary in the Calabrian cluster pine leaves and shoots. This may due to the difference of plant species.

Key Words: Calabrian cluster pine, Litter, Substratum, Plant, Soil, N, P, K, Terebinth

Doğu Akdeniz Bölgesinde Marn ve Konglomera Anamateryalleri Üzerindeki *Pinus brutia* Ten. (*Pinaceae*) ve *Pistacia terebinthus* L. (*Anacardiaceae*)'un Besin İçerikleri

Özet: Doğu Akdeniz Bölgesi kızılçam (*Pinus brutia* Ten., *Pinaceae*) ormanları ve menengiç (*Pistacia terebinthus* L., *Anacardiaceae*) topluluklarını içeren Akdeniz vejetasyonunun en önemli alanlarından biridir. Bu çalışma Doğu Akdeniz Bölgesinde (Türkiye) hem marn hem de konglomera anamateryallerinde yetişen kızılçam ve menengicin yaprak, sürgün, yaprak döküntüsü ve topraklarında ortalama C, N, P ve K içerikleri ve bu bitki topraklarında humik ve fulvik asit miktarlarını belirlemek için yapılmıştır. Her iki bitkinin yaprak, sürgün, yaprak döküntüsü ve toprak örneklerinin ortalama element içerikleri iki farklı anamateryal arasında kıyaslanmış olup anamateryal farklılığına rağmen sadece az ve oldukça güç fark edilen farklılıklar göstermiştir. Konglomera anamateryalinden oluşmuş menengiç topraklarında ortalama C ve N içerikleri marn anamateryalinden oluşmuş topraklardan anlamlı düzeyde daha yüksektir. Fakat bu değerler kızılçamda değişmemiştir. Menengicin yaprak ve dallarının ortalama P ve K içerikleri iki anamateryal arasında anlamlı olarak değişmişken, bunlar kızıl çamın yaprak ve dallarında değişmemiştir. Bu sonuç bitki türlerinin farklılığından kaynaklanabilir.

Anahtar Sözcükler: Kızılçam, Döküntü, Anamateryal, Bitki, Toprak, N, P, K, Menengiç

Introduction

The Mediterranean region covers the western and southern parts of the Anatolia peninsula. The lower belt of this region is the main area of the Mediterranean vegetation containing Calabrian cluster pine (*Pinus brutia* Ten., *Pinaceae*) forests and terebinth (*Pistacia terebinthus* L., *Anacardiaceae*) communities (Davis, 1965, 1966). In the Calabrian cluster pine forests of this region, terebinth usually occurs as an under layer of this plant (Atalay, 2002). The substrata are the major cause of variation in soil types, which in turn can control soil processes and soil nutrient dynamics (Yavitt, 2000). Few

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data are available about the influence of the substratum on nutrient concentration in the forest floor and upper soil layers (Klemmedson, 1994). In addition to the effect of substratum, there may be differences due to tree species in their nutrient contents and the rate of decomposition of their litters. Leaf litter of deciduous species may decompose more rapidly than coniferous species (Smolander & Kitunen, 2002). The potential effect of litter composition on soil N and C dynamics can vary widely among tree species (Cote et al., 2000). Coniferous litter has been found to reduce the availability of soil N because of its high lignin and low N content (Pastor et al., 1987).

Little is known about on the effect of substratum on soil properties and plants. Even less is known about organic matter humification, as determined by the amounts of humic and fulvic acid in soils (Aka Sağlıker & Darıcı, 2005); however, the topic is receiving increasing attention in Turkey.

This study aimed to provide information about the important soil parameters and a better understanding of the ecology of Calabrian cluster pine and terebinth, 2 plant species of this region that are widespread and highly adaptive. To do this, average C, N, P and K contents of leaves, shoots, leaf litters and soils were determined. Additionally, the amounts of humic and fulvic acids in Calabrian cluster pine and terebinth soils derived from marl and conglomerate substrata in the eastern Mediterranean region (Turkey) were determined.

Materials and Methods

This study was conducted at the Çukurova University campus in Adana at 2 sites with different substrata characterised by a semi-arid Mediterranean climate (mean annual precipitation: 663 mm; mean annual temperature: 18.7 °C) 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, Çukurova Süleyman Demirel Arboretum, located 3 km north-east of the campus, had marl substratum (altitude 105 m; lat 37°0.4′N, long 35°21′E). The other site, on the campus of Çukurova University, had conglomerate substratum (altitude: 135 m; lat 37°0.3′N, long 35°20′E). Marl and conglomerate substrata are dominant in this region. The localities of plant and soil samples in both sites were determined by Garmin mark GPS III software, version 2.0. Soils derived from marl and conglomerate substrata 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.

Calabrian cluster pine and terebinth trees were growing on both substrata, both trees were planted 25 years earlier and had grown naturally without human intervention. Element contents of leaves, shoots, leaf litters and soils were studied. Samples were collected 4 times between September 1999 and 2000 (6 September 1999, 5 March 2000, 6 June 2000 and 11 September 2000) from both sites. Overall, 80 trees (2 sites $\times$ 2 plants $\times$ 4 times $\times$ 5 samples) were sampled for each leaf, shoot, leaf litter and soil.

Fifteen complete and current-year leaves from each tree were collected from the upper third of the tree crown at each site (Madgwick and Mead, 1990). All 15 leaves were mixed for determining the nutrient status. The thin terminal shoots from which the 15 leaves were taken were also sampled and mixed. These samples were oven dried at 70 °C to a constant weight and then ground. Leaf litter sampling was performed by randomly locating a template (25 $\times$ 25 cm, converted to kg/m^2) on the litter and then carefully collecting all dead material within the inner area of the template. This was separated from other plant parts, such as small pieces of wood and other materials. Litter was also oven dried at 70 °C to a constant weight and ground. A soil sample (0-10 cm) from under each of the 5 Calabrian cluster pine and terebinth trees was collected and sieved through a 2-mm mesh sieve after removing obvious plant debris.

The soil texture was determined with a Bouyoucos hydrometer (Bouyoucos, 1951) and field capacity water (%) was determined 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 with a Scheibler calcimeter (Allison and Moodie, 1965) and cation exchange capacity (meq/100 g) was measured with 1 N CH_3COONH_4 by atomic absorption spectrophotometry (Chapman, 1965). The organic carbon content (%) of the soil and plant samples was determined by the Walkley & Black (1934) method; organic matter was obtained from the C values (%) and multiplied by 1.724 (Duchaufour, 1970). The organic N content (%) of these samples was determined by the

Kjeldahl method (Duchaufour, 1970). Phosphorus (P) and potassium (K) concentrations (%) were determined by digesting leaves, shoots and leaf litter in an HNO_3-$HClO_4$-H_2SO_4 mix (Jackson, 1958). Plant available P (mg/kg) and K (meq K/100 g) in the soil samples was determined by 0.5 M $NaHCO_3$ extraction (Olsen et al., 1954) and boiling nitric acid extraction (Özbek et al., 1995), respectively. P concentration was measured with a Unicam UV/Vis spectrophotometer and K concentration was measured with a 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 substrata. Differences between means were analysed with Tukey's test (Kleinbaum et al., 1998). The mean of 20 samples (5 samples × 4 sampling times for the average C, N, P and K values) was used for each leaf, shoot, leaf litter and soil sample for comparison. All statistical analyses were carried out using SPSS (version 11.5, 2002). Results are given as mean ± standard error in the tables. Differences in the analysis of variance were declared as significant at $P \leq 0.05$, 0.01 and 0.001.

Results

The physical and chemical properties of the soils from marl (loam textured) and conglomerate (sandy loam textured) substratum are given in Table 1. The sand and silt ratios (%) of soils with conglomerate were significantly different from soils with marl, for both plant species ($P < 0.001$). Clay ratios (%) of Calabrian cluster pine and terebinth soils did not differ significantly between the substrata ($P > 0.05$). Field capacity of Calabrian cluster pine soils varied significantly between the substrata ($P < 0.001$), but field capacity of terebinth soils did not vary significantly between the substrata ($P > 0.05$). Calabrian cluster pine soil pH did not significantly differ between the 2 substrata ($P > 0.05$), but the terebinth soil pH with conglomerate was significantly different from that with marl ($P < 0.001$). There were significant differences between the 2 substrata for the ratios of $CaCO_3$ in the Calabrian cluster pine and terebinth soils ($P < 0.01$ and $P < 0.001$, respectively). The cation exchange capacity (meq/100 g) of terebinth soils varied significantly with substratum type ($P < 0.001$), but did not differ significantly in the Calabrian cluster pine soil ($P > 0.05$). Soil organic C and N contents were significantly

Table 1. Physical and chemical characteristics of Calabrian cluster pine and terebinth soils from the 2 substrata.

Characteristic	Calabrian cluster pine		Terebinth	
	Marl	Conglomerate	Marl	Conglomerate
Sand (%)	41.0 ± 3.33	69.0 ± 1.32***	49.6 ± 0.83	75.0 ± 1.15***
Silt (%)	49.9 ± 3.13	22.1 ± 1.57***	40.7 ± 0.76	16.5 ± 1.17***
Clay (%)	9.14 ± 0.39	8.93 ± 0.47	9.69 ± 0.29	8.51 ± 0.68
FC (%)	31.6 ± 0.68	19.2 ± 0.57***	32.2 ± 0.20	27.1 ± 2.80
pH	7.71 ± 0.03	7.61 ± 0.01	7.65 ± 0.03	7.22 ± 0.05***
$CaCO_3$ (%)	23.2 ± 0.71	38.3 ± 0.99**	31.1 ± 0.35	7.50 ± 0.42***
CEC (meq/100 g)	26.8 ± 1.47	28.3 ± 0.71	25.4 ± 0.75	43.7 ± 3.99***
C (%)	1.43 ± 0.20	1.08 ± 0.18	1.89 ± 0.19	3.35 ± 0.40**
N (%)	0.10 ± 0.01	0.10 ± 0.01	0.14 ± 0.01	0.30 ± 0.03***
C/N ratio	13.9 ± 1.34	10.6 ± 1.36	13.2 ± 0.90	11.3 ± 0.50
OM (%)	2.47 ± 0.35	1.86 ± 0.32	3.26 ± 0.32	5.78 ± 0.69**
HA/OM (%)	18.6 ± 3.61	9.24 ± 1.71	12.6 ± 1.50	30.6 ± 4.50**
FA/OM (%)	81.4 ± 3.61	90.8 ± 1.71	87.4 ± 1.50	69.4 ± 4.50**
HA/FA ratio	0.24 ± 0.05	0.10 ± 0.02	0.15 ± 0.02	0.47 ± 0.01**

Data represent mean ± standard error (n = 5). **, ***Significant at the 0.01 and 0.001 probability levels, respectively. Statistical analyses (one-way ANOVA) were done separately for Calabrian cluster pine and terebinth. FC: field capacity; CEC: cation exchange capacity; OM: organic matter; HA: humic acid; FA: fulvic acid.

higher in the terebinth soils with conglomerate than in those with marl ($P < 0.01$ and $P < 0.001$, respectively), but it did not vary significantly between the 2 types of soils derived from marl and conglomerate of Calabrian cluster pine ($P > 0.05$). There were no significant differences between the 2 substrata in C/N ratios of soils of both plant species ($P > 0.05$). Even though organic matter, humic acid/organic matter, fulvic acid/organic matter ratios and humic acid/fulvic acid ratio of Calabrian cluster pine soils did not vary significantly between the 2 substrata ($P > 0.05$), all of these values differed significantly with respect to substratum differences in terebinth ($P < 0.01$).

The average C, N, P and K contents (%) in the Calabrian cluster pine leaves and shoots did not differ between the 2 substrata ($P > 0.05$, Table 2). While there were no significant differences between the substrata in the average C and N contents of terebinth leaves and shoots ($P > 0.05$), the average P ($P = 0.08$ for leaves, $P = 0.001$ for shoots) and K contents ($P = 0.000$ for both leaves and shoots) in the leaves and shoots of this plant varied significantly between the substrata. When the average elemental status of Calabrian cluster pine and terebinth leaf litters were compared between the 2 substrata, the average C and N contents (%) of Calabrian cluster pine leaf litter differed significantly ($P = 0.002$ and $P = 0.007$, respectively). The average available K content (meq/100g) was significantly different only between the substrata in the Calabrian cluster pine soils ($P = 0.000$). In the terebinth soils, the average C and N

Table 2. Influence of substratum on nutrient concentration in the leaves, shoots, leaf litters and soils of Calabrian cluster pine and terebinth.

		Calabrian cluster pine		Terebinth	
Parts	Elements	Marl	Conglomerate	Marl	Conglomerate
Leaf	C (%)	46.7 ± 1.30	48.7 ± 1.31	42.1 ± 2.65	44.7 ± 2.29
	N (%)	1.08 ± 0.05	1.29 ± 0.06	1.86 ± 0.17	1.51 ± 0.13
	P (%)	0.08 ± 0.004	0.09 ± 0.004	0.09 ± 0.006	0.07 ± 0.007**
	K (%)	0.75 ± 0.03	0.62 ± 0.04	0.95 ± 0.04	0.39 ± 0.05***
Shoot	C (%)	49.8 ± 1.17	45.7 ± 1.66	39.8 ± 1.76	42.1 ± 1.05
	N (%)	0.60 ± 0.03	0.71 ± 0.03	0.96 ± 0.06	0.96 ± 0.05
	P (%)	0.06 ± 0.002	0.05 ± 0.002	0.10 ± 0.008	0.07 ± 0.006**
	K (%)	0.41 ± 0.02	0.34 ± 0.02	0.73 ± 0.04	0.48 ± 0.06***
Leaf litter	C (%)	44.8 ± 1.43	34.5 ± 1.90**	36.1 ± 1.85	31.7 ± 2.39
	N (%)	0.89 ± 0.05	1.08 ± 0.04**	1.07 ± 0.04	1.08 ± 0.03
	P (%)	0.05 ± 0.002	0.05 ± 0.002	0.05 ± 0.002	0.08 ± 0.03
	K (%)	0.24 ± 0.03	0.20 ± 0.01	0.22 ± 0.02	0.20 ± 0.008
Soil	C (%)	1.23 ± 0.09	1.35 ± 0.11	1.91 ± 0.13	3.83 ± 0.24***
	N (%)	0.10 ± 0.005	0.10 ± 0.006	0.16 ± 0.006	0.33 ± 0.02***
	P (ppm)	7.09 ± 1.40	6.44 ± 1.24	6.14 ± 0.61	9.99 ± 1.44
	K (meq/ 100g)	2.32 ± 0.12	1.57 ± 0.10***	2.18 ± 0.08	2.33 ± 0.14
Leaf litter amount (kg/m^2)		0.63 ± 0.11	1.30 ± 0.09	1.07 ± 0.31	1.37 ± 0.23

Data represent mean ± standard error (n = 15 for terebinth leaves, n = 20 for the others).

**, ***Significant at the 0.01 and 0.001 probability levels, respectively. Statistical analyses (general linear model) were done separately for Calabrian cluster pine and terebinth.

contents (%) varied significantly between the 2 substrata ($P = 0.000$ for both C and N). The average leaf litter amounts (kg/m^2) of both Calabrian cluster pine and terebinth did not differ between the substrata ($P > 0.05$).

Discussion

Data revealed significant differences between the physical and chemical characteristics of soils derived from marl and conglomerate substrata of both Calabrian cluster pine and terebinth (Table 1). Concentrations of the average C, N, P and K (%) in the leaves, shoots, leaf litters and soils of both Calabrian cluster pine and terebinth exhibited only a few relatively subtle differences, despite the differences in substrata (Table 2). The results showed that both plant species can adapt to their environments very well, without discriminating between substrata. For example, the average C, N, P and K contents of leaves and shoots of Calabrian cluster pine and leaf litters of terebinth did not vary between the substrata. Zas and Serrada (2003) reported no significant differences in the P foliar concentrations of *Pinus radiata* D.Don between different parent materials. The average P and K concentrations of terebinth leaves and shoots varied significantly between the 2 substrata (Table 2); however, the average P and K contents of Calabrian cluster pine leaves and shoots did not. This may have been due to the difference of plant species, because deciduous species may draw back N, K and P accumulated in their leaves before they shed their leaves (Heller, 1993). When coniferous species, which include Calabrian cluster pine, are compared to deciduous species, which include terebinth, they have many differences, such as crown structure, branch numbers, foliage biomass, leaf area and foliar nutrients levels.

When the average elemental status of Calabrian cluster pine and terebinth leaf litters were compared between the 2 substrata, the average C and N contents of Calabrian cluster pine leaf litter differed significantly (Table 2). Differences between the plant species in C and N concentrations of the leaf litter are in accordance with the results of previous studies carried out in different types of forest ecosystems (Klemmedson, 1994; Hongve, 1999; Cote et al., 2000). The amount of organic matter produced by plant types, its composition and decomposing ability can vary widely for each plant type (Aber et al., 1990; Hobbie, 1992; Lovett et al., 2004).

Concentrations of C and N in the terebinth soils derived from conglomerate substratum were significantly higher than those derived from marl substratum in a year. However, there were no significant differences between the 2 substrata in the C and N concentrations of the Calabrian cluster pine soils. Available K content of the plant soils was significantly different between the substrata (Table 2). Yavitt (2000) compared 3 parent materials (andesite, limestone, and conglomerate) and found no differences in concentrations of N, P and S related to the parent materials 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 vary depending on different substrata. Parent materials become the ultimate cause of variation in soil types, which in turn can control soil processes and soil nutrient dynamics (Jenny, 1980; Binkley et al., 1995). In the current study, the higher N concentration in the terebinth leaves, shoots and leaf litters compared to those of Calabrian cluster pine indicated greater accumulation of soil N in the terebinth. Such difference may be due to different tree species. The soils under birch have often been found to differ from the soils under conifers (Haines & Cleveland, 1981; Côte et al., 2000; Smolander & Kitunen, 2002). The organic matter that is incorporated in the mineral soil through biological activity and the soluble organic matter that is leached from the forest floor periphery may be of higher quality in deciduous than in coniferous forests (Finér et al., 1997). Additionally, humic and fulvic acid/organic matter rates of terebinth soils with conglomerate were 30.6% and 69.4%, respectively. These rates in the terebinth soils with marl were 12.6% and 87.4%, respectively (Table 1). The humus of forest soils (Alfisols, Spodosols and Ultisols) are characterised by a high content of fulvic acids. The low-molecular-weight fulvic acids have lower C contents than the high-molecular-weight humic acids. Fulvic acids also have higher solubility than humic acids. Therefore, they can be easily removed from the soil by precipitation (Stevenson, 1982; Özbek et al., 1995). Soils derived from conglomerate substratum have a higher humic acid ratio than soils from marl; therefore, such soil may have more protection against loss of organic matter through precipitation.

In conclusion, the results of this study show that C, N, P and K contents of leaves, shoots, leaf litters and soils of Calabrian cluster pine and terebinth trees growing on marl and conglomerate substrata in the eastern Mediterranean region of Turkey are partially affected by differences of plant and substratum in a year.

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