JOURNAL OF THE FACULTY OF FORESTRY ISTANBUL UNIVERSITY
İSTANBUL ÜNİVERSİTESİ ORMAN FAKÜLTESİ DERGİSİ
ISSN: 0535-8418 e-ISSN: 1309-6257

Online available at / Çevrimiçi erişim
http://dergipark.gov.tr/jffiu - http://dx.doi.org/10.17099/jffiu.301602
Research Article / Araştırma Makalesi

Litterfall and nutrients return to soil in pure and mixed stands of oak and beech

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Received (Geliş): 31.10.2016 - **Revised (Düzeltme):** 29.11.2016 - **Accepted (Kabul):** 02.01.2017

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Abstract: Litterfall is a significant pathway for the return of nutrients and carbon (C) to the soil in forest ecosystems. It provides long-term maintenance of nutrients in the forest ecosystem. For maintaining healthy forest ecosystems, knowledge about litterfall, energy, and nutrient inputs to the soil biota is important. This study was aimed to determine litterfall and nutrient return to soil in pure and mixed stands of oak (*Quercus petraea* (Mattuschka) Liebl.) and beech (*Fagus orientalis* Lipsky) in Atatürk Arboretum, Turkey. Litterfall has been collected over 3 years from 2009 to 2011 at all three sites. Litter traps were used for this purpose, and the trapped samples were sorted into fractions, which included leaves (foliar), branches/twigs, and others (e.g., acorn, flowers, bark, etc.). The concentrations of 14 elements (C, N, P, K, Ca, Na, Mg, Mn, Fe, Al, Zn, Pb, Ni, and Cu) were analyzed. The highest amount of litterfall in the three areas was measured in 2010. The average total litterfall ranged from 3947 to 4578 kg/ha. The average amounts of leaflitter in oak, beech, and oak–beech sites were 86%, 62%, and 75%, respectively. Nutrient concentrations were higher in leaves and the least in branches and twigs. Element concentrations generally showed a descending order as C>Ca>N>Mg>K>Mn>P>Al>Fe>Na>Zn>Cu>Ni> in all the sites. The pure and mixed sites were not significantly different by years, but there was a significant difference in the nutrient concentrations of litterfall fractions between the two sites.

Keywords: Litter, litterfall compartments, macronutrients, micronutrients, oak, beech, mixed stands

Saf ve karışık meşe, kayın meşcerelerinde ölü örtü dökümü ve bu yolla toprağa verilen besin maddeleri

Özet: Ölü örtü dökümü ve ayrışması, besin maddelerinin toprak üstü ekosistemden toprak sistemine geçişini sağlayan önemli bir süreçtir. Orman ekosisteminde uzun dönem besin durumunun korunmasını sağlar. Orman ekosistemlerinin sağlıklı işleyebilmesi için, ölü örtü dökümü ile toprak canlıları için enerji ve besin girdisinin bilinmesi gerekmektedir. Atatürk Arboretumu'nda, saf ve karışık meşe (*Quercus petraea* (Mattuschka) Liebl.), kayın (*Fagus orientalis* Lipsky) meşcerelerinde yürütülen bu çalışmanın amacı ölü örtü dökümü ve bu yolla 2009-2011 yılları arasında ekosisteme geri verilen besin madde miktarının belirlenmesidir. Bu amaç ile belirlenen çalışma alanlarında ölü örtü kapanları kullanılmıştır. Kapanlara düşen bitki kısımları yaprak, dal ve diğer kısımlar (palamut, çiçek, kabuk vb.) olarak ayrılmıştır. Örneklerde C, N, P, K, Ca, Na, Mg, Mn, Fe, Al, Zn, Pb, Ni ve Cu içerikleri belirlenmiştir. Çalışmada her üç alanda da en yüksek ölü örtü döküm miktarı 2010 yılında ölçülmüştür. Toplam ölü örtü dökümü örnekleme alanlarında ortalama 3947-4578 kg/ha olarak bulunmuştur. Dökümle gelen yaprak miktarı ortalama olarak meşe, kayın ve meşe-kayın alanlarında sırası ile %86, %62 ve %75 olarak belirlenmiştir. Element yoğunluğu genel olarak en fazla yapraklarda en az dallarda bulunmaktadır. Tüm alanlarda element yoğunluğunun genel olarak C>Ca>N>Mg>K>Mn>P>Al>Fe>Na>Zn>Cu>Ni>Pb şeklinde sıralandığı ortaya çıkmıştır. Döküm yolu ile gelen ölü örtü elemanları arasında istatistiksel fark bulunurken saf ve karışık alanlar arasında ve yıllara göre istatistiksel fark bulunmamıştır.

Anahtar Kelimeler: Ölü örtü, döküm bileşenleri, Makro besin maddeleri, Mikro besin maddeleri, meşe, kayın, karışık meşcere

Cite (Atıf) : Çakır, M., Akburak, S. 2017. Litterfall and nutrients return to soil in pure and mixed stands of oak and beech. *Journal of the Faculty of Forestry Istanbul University* 67(2): 185-200. DOI: 10.17099/jffiu.301602

1. INTRODUCTION

Litterfall and decomposition are an important process that enables the transition of nutrients from the above-ground system to the below-ground system (Li et al., 2011; Berg ve McClaugherty, 2014) and protection of the nutrients in the forest ecosystem for a long time (Irmak and Çepel, 1968). Furthermore, litterfall is the main source of the organic matter and carbon that accumulates in the soil (Sayer, 2006). Therefore, litterfall is the key variable that is used to estimate, model and determine the amount of carbon accumulating in the soil (Liski et al., 2005).

For the proper functioning of forest ecosystems, energy and nutrient input is required for the soil organisms by means of litterfall (Staaf and Berg, 1981). Litter that is converted by decomposing organisms into a form which can be taken by plants is of vital importance for the increment and growth of forest trees (Irmak and Çepel, 1974). The nutrient content of litterfall depends on various factors such as tree species and mixture, soil properties and climate (Ukonmaanaho et al., 2008). Litter has a direct and indirect effect on the physical and chemical properties of the soil, available nutrients and also the diversity of soil fauna and flora (Sayer, 2006).

Litterfall is not only an important component of net primary production but also provides important information about the effect of climate change on forests during flowering, budding and seed set periods as a phonological observation. ICP Forests involves the monitoring of litterfall of different tree species depending on climate change (ICP-Forests, 2010). In conclusion, monitoring is not only the total litterfall or leaf litter but also fall of other plant parts of trees will improve our knowledge about the nutrient cycle and phonological reactions of forest trees depending on climate change.

Litterfall has been studied for several years (Müller, 1887) and the reviews try to explain this matter from a holistic perspective (Bray and Gorham, 1964; Meentemeyer et al., 1982; Vogt et al., 1986; Sayer, 2006). Although studies were conducted in beech, oak, black pine stands (Irmak and Çepel, 1968; Çakır, 2013; Sargıncı, 2014) and Calabrian pine stands (Çepel et al., 1988) in Turkey, the number of the studies is quite limited. The studies conducted in Turkey were conducted in pure forests. Nevertheless, the mixed stands has had an important effect on the ecosystem and have been studied in recent years (Enright, 1999; Staelens et al., 2003). It is reported that mixed forests are more productive than pure forests (Pretzsch et al., 2010), and their productivity is due to the nutrients and elements from the litterfall of varying quality (Prescott, 2005). In this context, mixed stands and pure stands were compared for the first time in Turkey with respect to litterfall and some elements.

The purpose of this study conducted in oak and beech stands in Atatürk Arboretumu was to determine the litter fall and the amount of nutrients and some elements (C, N, P, K, Ca, Mg, Mn, Fe, Cu, Zn, Ni, Na, Al, Pb) given back to the ecosystem in that way in the pure and mixed stands.

2. MATERIALS AND METHOD

2.1 Study Site

Established in 1949, Atatürk Arboretum is located on an area of 296 ha in the southeast of Belgrad Forest in İstanbul-Sarıyer. The sample plots were selected from the natural pure oak, pure beech and mixed oak-beech stands located in Ataturk Arboretum in Belgrad Forest (Figure / Şekil 1). They are on north latitude 41°09'48" - 41°10'55" and east longitude 28°57'27" - 28°59'27" do (Karaöz, 1991).

The soils in Atatürk Arboretum don’t contain lime ($CaCO_3$) and their pH ranges from 4.5 to 5.0. The soils in the research area are Luvisol without any drainage problem (WRB, 2006). The overall texture class is loam. According to the data of Bahçeköy Meteorology Station, the mean annual precipitation in 1975-2008 was 1121 mm, average temperature was 13°C, with the highest average being 17.8°C and lowest average being 9°C. The vegetation period is 7.5 months (230 days). The elevation from the sea level ranges from 65 to 166 m. The overall aspect is south-east and south- west, however, there are many slopes with different aspects and the inclination is 10%-15%.

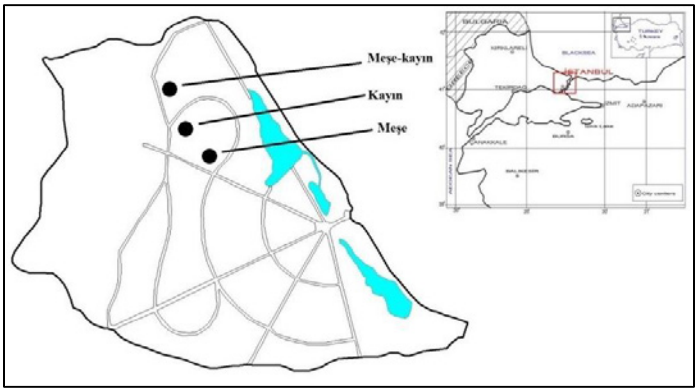

Figure 1. Pure and mixed stands in Atatürk Arboretum in Istanbul
Şekil 1. İstanbul Atatürk Arboretumu içerisinde bulunan saf ve karışık alanlar

Litterfall traps were selected from the same-age oak (*Quercus petraea* (Mattuschka) Liebl), beech (*Fagus orientalis* Lipsky) and Oak-Beech mixed stands (Table / Tablo 1). These sites were established in 1949 by planting with natural species (Şengönül and Yılmaz, 2008).

Table 1. Stands characteristics of pure and mixed stands
Tablo 1. Saf ve Karışık alanlara ait meşcere özellikleri

		Diameter $d_{1.30}$ (cm)	Height (cm)	Age
Pure	**Oak**	10.28	16.8	60-65
	Beech	18.15	22.3	60-65
Mixed	**Oak**	14.20	22.5	60-65
	Beech	20.82	22.3	60-65

2.2 Litterfall and Chemical Analyses

In order to determine the amount of litterfall, 0.3 m-deep traps covering an area of 0.7 m² were installed with holes at the bottom to prevent the accumulation of water at a height of 1 m from the ground level at 9 different points in each study sites in August 2009 (Austin ve Vivanco, 2006; ICP-Forests, 2010). The plant parts falling into the traps were collected from 2009 to 2011. The litter samples were transported to the laboratory, dried in the oven at 65 °C until the constant weight. The dried samples were sorted into leaves, branches and other parts (acorn, flower, bark etc.), weighted and ground after their dry weights were determined.

Subsamples (0.5 g) was taken from the ground samples and placed in teflon tubes after which 4 ml concentrated HNO_3 (nitric acid) and 2 ml H_2O_2 (hydrogen peroxide) were added and samples were converted into solution in microwave digestion systems (Berghof Speed Wave). The solutions were then prepared with ultra-pure water until the final volume reached 50 ml and stored at 4 Cº until they were analyzed. Phosphorus (P), Potassium (K), Calcium (Ca), Sodium (Na), Magnesium (Mg), Manganese (Mn), Iron (Fe), Aluminum (Al), Zinc (Zn), Lead (Pb), Nickel (Ni) and Copper (Cu) concentrations of the solutions were determined by ICP-OES (Perkin Elmer Optima 7000 DV) instrument. In order to validate the accuracy of the method and the calibration of the device, certified sample (NIST 1575a Pine needles) was also analyzed. The measurement of the instrument and the certificate values are shown in Table / Tablo 2. Carbon and nitrogen analyses were performed in C/N analyzer (LECO Truspec 2000) according to the dry combustion (Dumas) method.

2.3 Statistical analysis

In order to determine the spatial and component variations in the nutrient contents by years, one-way ANOVA test was applied. When these variations were found to be significant (α=0.05) at the confidence interval of 95%, Tukey's test was performed. Statistical analyses were conducted in IBM Statistical Package for the Social Sciences (IBM SPSS Statistics, Armonk, NY, USA) 21.0 package software.

Table 2. The values of device and certificate
Tablo 2. Cihaz (ICP-OES, Perkin Elmer) değerleri ve sertifika değerleri

	Measurement Value		Certificate value	
	Mean (mg kg^{-1})	Sd (±)	Mean (mg kg^{-1})	Sd (±)
Pb	0.252	0.116	0.167	0.015
Cd	0.224	0.0305	0.233	0.004
Ni	1.517	0.0089	1.47	0.1
Al	546.1	3.79	580	30
Fe	45.59	0.962	46	2
Ca	2438	66.8	2500	100
Na	65.02	5.748	63	1
K	3984	44.5	4170	80
Zn	37.95	0.157	38	2
Cu	2.64	0.0776	2.8	0.2
Mg	920.7	10.47	1060	170
Mn	496.9	3.25	488	12
P	1027	9.7	1070	80
Cr	0.47	0.0014	0.30-0.50	

Sd: Standard deviation

3. RESULTS AND DISCUSSION

3.1 Litterfall in Pure and Mixed Sites

Total litterfall was found to be 3947-4578 kg ha^{-1} on average for all plots. From 2009 to 2011, the average amount of litterfall was 3514-4708 kg ha^{-1} in the oak site, and 3602-6160 kg ha^{-1} in the beech sit while it was 3227-6543 kg ha^{-1} in the oak-beech mixed site.

As for the amount of leaf litter from 2009 to 2011, the highest amount of leaf litter on average was found in oak site (3402 kg ha^{-1}), while the lowest leaf litter was found in beech site (2473 kg ha^{-1}). The lowest amount of branch litter was in the beech site with 352 kg ha^{-1} while the highest amount of branch litter was in the oak-beech mixed site with 472 kg ha^{-1}. The highest amount of the other parts that were seeds, barks and plant parts of other species (e.g. *Hedera helix*) was found in the beech site (1483 kg ha^{-1}) while the lowest amount was in the oak site (107 kg ha^{-1}). As regards the distribution of the total litterfall amount by years, the highest amount of total litterfall was found in 2010 in the pure and mixed stands (Table / Tablo 3).

Majority of the litterfall is composed of leaves. The average amount of leaf litter was 86% in the oak site, 62% in the beech site and 75% in the oak-beech mixed site. The highest amount of branch litter was in the oak site (10%) while the lowest amount of branch litter was in the beech site (6%), while the highest amount of other plant parts was in the beech site (30%) while the lowest amount was in the oak site (3%) (Table / Tablo 3).

Table 3. The annual amount of litterfall (kg ha^{-1}) ratios to total amount of litterfall (%), which separated leaves, branches/twigs, and others
Tablo 3. Yıllık döküm miktarı (kg/ha) ve toplam döküm miktarına oranları (%) ölüörtü, yaprak, dal ve diğer olarak ayrılmıştır

		Oak Leaves (kg ha^{-1})	Beech Leaves (kg ha^{-1})	Branches (kg ha^{-1})	Other (kg ha^{-1})	Total
Oak	2009	3247.1 (92.4)	-	216.4 (6.2)	51.1 (1.5)	3514.6
	2010	4003.8 (85)	-	592.3 (12.6)	112.3 (2.4)	4708.4
	2011	2955.1 (81.7)	-	505 (14)	158 (4.4)	3618.1
Beech	2009	-	3185.4 (80.2)	118.8 (3)	668.8 (16.8)	3973
	2010	-	2702.7 (43.9)	771.8 (12.5)	2686.2 (43.6)	6160.7
	2011	-	2342.3 (65)	165.8 (4.6)	1094.1 (30.4)	3602.2
Oak-Beech	2009	1504.3 (41.7)	1926.1 (53.4)	98.3 (2.7)	81.5 (2.3)	3610.2
	2010	1591.7 (24.3)	2032.4 (31.1)	1056.7 (16.1)	1862.5 (28.5)	6543.3
	2011	1162.7 (36)	1305.4 (40.4)	260.2 (8.1)	499.4 (15.5)	3227.7

3.2 Nutrient contents and element flow of litter components

There were temporal and spatial statistical differences between the element concentrations of the litterfall components ($P<0,05$) (Table / Tablo 4). The highest element concentration was found to be in C, Ca, Mg, K and Mn, respectively, in the leaves of the oak trees with while it was in C, Ca, Mn, Mg and K, respectively, in the beech trees. Ca, K and Mg had the highest concentration in the branches and other parts (Table / Tablo 4). The lowest concentration was found in Pb, Ni, Cu, Zn, Al and Fe in all sites (Table / Tablo 4). Overall, the highest element concentration was found in the leaves whereas the lowest element concentration was found in the branches (Table / Tablo 4). As for the distribution by years, there were statistically significant differences between the concentrations of the elements by years except Zn and Ca in oak leaves (Table / Tablo 4). As for the beech leaves, there was a statistical difference between the element concentration of Pb, Mn, Mg, Cu, Al, Na and K over the years (Table / Tablo 4).

As regards the element concentration of the total litterfall, temporal and spatial statistical differences were found ($P<0,05$) (Table / Tablo 5). Only the concentration of Zn in the total litterfall varied across the years in the oak site (Table 5). In the beech site, however, a temporal difference was found in the concentration of P, Mn, Ca and Na, while a temporal difference was found in the concentration of Ni, Mn, Ca and Na in the oak-beech site (Table / Tablo 5).

While there was a statistical difference between the litterfall components (leaf, branch and others), non-significant difference was observed between the pure and mixed stands and across the years (Table / Tablo 5). The highest nutrient flow was found in the leaves (Table / Tablo 6). The total nutrient flow in the branches and other parts varied across the years. The total amount of nutrients in the litter was in descending order as C>Ca>N>Mg>K>Mn>P>Al>Fe>Na>Zn>Cu>Ni>Pb in all sites. The highest total nutrient flow (except Mn) was found in 2010 in the oak-beech mixed stand (Table / Tablo 6).

Table 4. Results of ANOVA of litterfall elements contents according to annuals Mean (Sd)
Tablo 4. Yıllara göre döküm elemanlarının element içeriklerine ait ANOVA sonuçları

Time	Area	Comp.	Zn (mg kg^{-1})	Pb (mg kg^{-1})	Ni (mg kg^{-1})	Cu (mg kg^{-1})	Al (mg kg^{-1})	Fe (mg kg^{-1})	P (mg kg^{-1})	Na (mg kg^{-1})	Mn (mg kg^{-1})	Mg (mg kg^{-1})	Ca (mg kg^{-1})	K (mg kg^{-1})	C (%)	N (%)
2009	Oak	OL	6.637 ^{ac} (0.646)	1.743 ^{d} (0.106)	3.317 ^{e} (0.059)	4.873 ^{d} (0.006)	115.457 ^{g} (1.220)	134.083 ^{f} (1.494)	182.627 ^{d} (1.674)	210.380 ^{f} (2.885)	750.920 ^{d} (7.044)	1544.870 ^{g} (32.439)	13619.317 ^{g} (56.557)	1224.733 ^{c} (4.809)	48.452 ^{c} (0.035)	1.103 ^{f} (0.029)
		OB	4.557 ^{abc} (0.259)	4.037 ^{g} (0.107)	1.947 ^{a} (0.074)	6.293 ^{g} (0.035)	75.023 ^{c} (0.599)	93.417 ^{b} (1.647)	141.463 ^{b} (1.328)	229.100 ^{h} (2.540)	456.810 ^{b} (4.372)	939.770 ^{c} (2.645)	15010.107 ^{h} (62.752)	2279.270 ^{i} (59.573)	48.377 ^{bc} (0.135)	0.592 ^{a} (0.030)
		Other	5.060 ^{abc} (0.356)	0.723 ^{a} (0.031)	1.977 ^{a} (0.015)	4.623 ^{c} (0.015)	103.693 ^{f} (0.403)	104.260 ^{c} (1.811)	229.983 ^{e} (0.270)	201.333 ^{e} (0.999)	1164.683 ^{e} (7.709)	1379.783 ^{f} (14.927)	9475.587 ^{a} (50.106)	2809.047 ^{i} (18.780)	48.948 ^{d} (0.147)	0.976 ^{e} (0.018)
	Beech	BL	13.333 ^{d} (3.309)	1.387 ^{b} (0.154)	3.267 ^{e} (0.026)	4.270 ^{b} (0.020)	99.417 ^{e} (1.395)	130.750 ^{f} (1.846)	138.373 ^{b} (2.114)	187.993 ^{d} (1.149)	1665.050 ^{h} (17.411)	1391.367 ^{f} (24.513)	10488.700 ^{c} (91.221)	1461.540 ^{f} (13.492)	48.059 ^{ab} (0.061)	0.883 ^{d} (0.041)
		BB,	12.387 ^{d} (4.025)	2.993 ^{f} (0.110)	2.410 ^{b} (0.010)	6.893 ^{i} (0.075)	61.153 ^{b} (0.665)	67.730 ^{a} (0.408)	193.480 ^{d} (3.112)	160.093 ^{b} (2.881)	451.917 ^{b} (7.599)	864.693 ^{b} (7.801)	12448.203 ^{e} (32.506)	1737.597 ^{g} (19.760)	48.837 ^{d} (0.014)	0.551 ^{a} (0.009)
		Other	2.310 ^{b} (0.145)	1.533 ^{c} (0.042)	6.167 ^{g} (0.042)	5.073 ^{e} (0.021)	104.827 ^{f} (1.028)	109.120 ^{d} (1.382)	140.700 ^{b} (0.428)	217.807 ^{c} (7.886)	1525.440 ^{g} (24.200)	1691.867 ^{h} (6.292)	12758.883 ^{f} (66.973)	1370.360 ^{e} (41.993)	47.775 ^{a} (0.064)	0.874 ^{d} (0.011)
	Oak-Beech	OL	7.607 ^{c} (1.982)	1.707 ^{d} (0.047)	8.310 ^{h} (0.217)	3.993 ^{a} (0.032)	97.273 ^{d} (1.833)	104.943 ^{c} (1.791)	152.317 ^{c} (0.391)	167.027 ^{c} (6.328)	1335.570 ^{f} (8.086)	1347.393 ^{e} (4.985)	9655.547 ^{b} (41.700)	890.790 ^{b} (10.812)	49.544 ^{e} (0.476)	0.682 ^{b} (0.041)
		BL	12.970 ^{d} (3.048)	2.773 ^{e} (0.090)	8.773 ^{i} (0.038)	5.270 ^{f} (0.017)	405.307 ^{i} (0.526)	402.170 ^{g} (5.326)	195.237 ^{d} (4.855)	216.077 ^{gf} (3.838)	1732.420 ^{i} (12.544)	1675.047 ^{h} (16.376)	10975.563 ^{d} (196.782)	1299.553 ^{d} (14.326)	47.815 ^{a} (0.009)	0.903 ^{d} (0.013)
		B	3.373 ^{ab} (0.745)	3.087 ^{f} (0.015)	4.393 ^{f} (0.087)	6.393 ^{h} (0.025)	50.990 ^{a} (0.996)	65.503 ^{a} (0.333)	195.723 ^{d} (0.793)	235.373 ^{h} (2.533)	684.753 ^{c} (7.892)	1092.707 ^{d} (17.694)	18152.570 ^{i} (104.309)	1939.513 ^{h} (17.351)	49.495 ^{e} (0.355)	0.764 ^{c} (0.051)
		Other	4.350 ^{abc} (1.422)	4.807 ^{h} (0.006)	2.787 ^{d} (0.032)	4.573 ^{c} (0.071)	118.667 ^{h} (1.031)	118.460 ^{e} (1.078)	71.320 ^{a} (1.187)	133.053 ^{g} (0.420)	308.133 ^{a} (3.091)	626.073 ^{a} (4.274)	26539.677 ^{i} (164.694)	654.273 ^{a} (10.086)	48.055 ^{ab} (0.206)	0.552 ^{a} (0.004)

Table 4. Results of ANOVA of litterfall elements contents according to annuals Mean (SD) (Continued)
Tablo 4. Yıllara göre döküm elemanlarının element içeriklerine ait ANOVA sonuçları (devamı)

Time	Area	Comp.	Zn (mg kg-1)	Pb (mg kg-1)	Ni (mg kg-1)	Cu (mg kg-1)	Al (mg kg-1)	Fe (mg kg-1)	P (mg kg-1)	Na (mg kg-1)	Mn (mg kg-1)	Mg (mg kg-1)	Ca (mg kg-1)	K (mg kg-1)	C (%)	N (%)
2010	Oak	OL	4.780 ^{a}	1.907 ^{c}	4.393 ^{e}	5.937 ^{a}	179.353 ^{c}	221.603 ^{d}	195.783 ^{a}	244.893 ^{e}	694.433 ^{e}	1485.163 ^{f}	15881.363	1363.980 ^{d}	48.404 ^{bc}	1.071 ^{f}
			(2.262)	(0.090)	(0.030)	(0.049)	(3.530)	(0.574)	(2.468)	(4.520)	(4.057)	(23.697)	^{g} (242.506)	(18.768)	(0.042)	(0.026)
		OB	13.580 ^{d}	4.060 ^{g}	2.160 ^{a}	6.927 ^{f}	109.377 ^{b}	121.643 ^{b}	139.287 ^{b}	212.880 ^{cd}	314.930 ^{b}	806.767 ^{b}	15358.233	1521.646 ^{f}	49.075 ^{c}	0.555 ^{b}
			(1.367)	(0.141)	(0.020)	(0.025)	(1.313)	(2.437)	(2.657)	(0.667)	(5.193)	(5.301)	^{f} (108.886)	(12.988)	(0.392)	(0.018)
		Other	3.660 ^{a}	0.903 ^{a}	3.920 ^{c}	5.330 ^{c}	383.057 ^{e}	499.167 ^{g}	262.023 ^{c}	184.123 ^{b}	171.500 ^{a}	898.807 ^{c}	7253.753 ^{a}	3309.003 ^{i}	46.100 ^{a}	0.755 ^{c}
			(2.415)	(0.129)	(0.034)	(0.055)	(5.244)	(7.284)	(1.017)	(5.657)	(0.516)	(13.543)	(66.357)	(24.626)	(0.215)	(0.006)
	Beech	BL	9.470 ^{bc}	1.807 ^{bc}	3.930 ^{c}	5.450 ^{d}	176.083 ^{c}	203.193 ^{c}	190.673 ^{d}	215.250 ^{d}	1918.533 ^{i}	1424.730 ^{e}	13218.247 ^{c}	1108.743 ^{c}	47.168 ^{ab}	0.835 ^{d}
			(0.400)	(0.119)	(0.010)	(0.085)	(2.374)	(2.087)	(2.271)	(7.521)	(20.228)	(35.053)	(83.675)	(17.840)	(0.0210)	(0.001)
		BB,	5.897 ^{ab}	2.327 ^{e}	3.410 ^{b}	3.727 ^{a}	93.390 ^{a}	104.813 ^{a}	51.690 ^{e}	172.770 ^{a}	343.720 ^{c}	549.167 ^{a}	11342.290	720.783 ^{a}	48.305 ^{bc}	0.229 ^{a}
			(0.287)	0.04726	(0.020)	(0.011)	(2.071)	(0.768)	(0.900)	(1.474)	(1.715)	(8.007)	^{b} (36.821)	(6.676)	(0.087)	(0.004)
		Other	5.417 ^{a}	3.2167 ^{f}	6.303 ^{g}	8.857 ^{g}	376.070 ^{e}	447.363 ^{f}	242.080 ^{f}	250.387 ^{ef}	1272.790 ^{g}	1396.023 ^{e}	15485.803 ^{f}	1603.403 ^{g}	47.467 ^{abc}	0.928 ^{e}
			(1.200)	(0.080)	(0.025)	(0.056)	(3.002)	(3.913)	(2.459)	(1.748)	(2.560)	(2.344)	(90.647)	(20.472)	(0.133)	(0.094)
	Oak-Beech	OL	4.647 ^{a}	1.707 ^{b}	8.970 ^{i}	5.697 ^{e}	175.840 ^{c}	199.827 ^{c}	214.287 ^{g}	205.477 ^{c}	1570.370 ^{h}	1680.050 ^{h}	14105.480 ^{e}	1132.510 ^{c}	47.097 ^{ab}	1.225 ^{g}
			(0.301)	(0.050)	(0.144)	(0.075)	(5.166)	(1.971)	(2.757)	(3.860)	(2.543)	(15.961)	(150.796)	(6.046)	(1.581)	(0.049)
		BL	12.690 ^{cd}	2.163 ^{d}	6.580 ^{h}	5.003 ^{b}	218.687 ^{d}	259.237 ^{e}	219.467 ^{h}	212.807 ^{dc}	1822.440 ^{i}	1608.770 ^{g}	11243.347	1016.863 ^{b}	45.958 ^{a}	1.245 ^{g}
			(5.692)	(0.085)	(0.065)	(0.032)	(2.197)	(8.017)	(5.149)	(4.922)	(20.441)	(25.872)	^{b} (37.385)	(13.351)	(2.019)	(0.027)
		B	13.677 ^{d}	4.400 ^{h}	4.257 ^{d}	6.823 ^{f}	115.360 ^{b}	123.890 ^{b}	157.423 ^{i}	259.693 ^{g}	526.400 ^{d}	877.870 ^{c}	15745.093	1395.630 ^{e}	47.859 ^{bc}	0.863 ^{de}
			(0.837)	(0.112)	(0.028)	(0.080)	(1.546)	(1.498)	(2.941)	(9.248)	(3.372)	(17.060)	^{g} (106.044)	(8.772)	(0.474)	(0.049)
		Other	5.147 ^{a}	4.587 ^{i}	5.620 ^{f}	9.387 ^{h}	1116.890 ^{f}	588.630 ^{h}	331.790 ^{i}	255.876 ^{gf}	907.663 ^{f}	1175.233 ^{d}	13566.947	2419.503 ^{h}	46.844 ^{ab}	1.295 ^{g}
			(0.324)	(0.032)	(0.034)	(0.083)	(14.849)	(2.040)	(2.919)	(0.662)	(2.235)	(7.670)	^{d} (110.518)	(16.022)	(0.765)	(0.009)

Within a column, means with a different letter are significantly different at α=0.05 level,
OL: Oak Leaves, OB: Oak Branches, BL: Beech Leaves, BB: Beech Branches, B: Branches. Comp.: Components

Table 4. Results of ANOVA of litterfall elements contents according to annuals Mean (SD) (Continued)
Tablo 4. Yıllara göre döküm elemanlarının element içeriklerine ait ANOVA sonuçları (devamı)

Time	Area	Comp.	Zn (mg kg^{-1})	Pb (mg kg^{-1})	Ni (mg kg^{-1})	Cu (mg kg^{-1})	Al (mg kg^{-1})	Fe (mg kg^{-1})	P (mg kg^{-1}))	Na (mg kg^{-1})	Mn (mg kg^{-1})	Mg (mg kg^{-1})	Ca (mg kg^{-1})	K (mg kg^{-1})	C (%)	N (%)
2011	Oak	OL	1.457^{a} (0.406)	2.050^{a} (0.034)	2.830^{b} (0.020)	5.650^{b} (0.051)	322.720^{d} (5.240)	306.077^{e} (1.976)	176.660^{a} (0.655)	209.140^{e} (1.083)	571.047^{b} (4.258)	1425.040^{g} (7.893)	16767.197^{g} (308.941)	1297.097^{f} (10.062)	48.935^{d} (0.214)	1.479^{e} (0.236)
		OB	4.860^{b} (0.720)	4.030^{f} (0.124)	1.717^{a} (0.025)	7.243^{e} (0.125)	202.960^{b} (4.261)	218.783^{b} (1.374)	151.500^{b} (1.504)	202.367^{de} (7.800)	445.117^{a} (2.058)	922.380^{b} (15.149)	16055.930^{f} (174.662)	1506.283^{g} (11.276)	49.587^{e} (0.170)	0.629^{a} (0.015)
		Other	10.057^{c} (1.735)	7.743^{h} (0.068)	6.670^{h} (0.062)	10.907^{h} (0.058)	1167.760^{g} (12.670)	1255.227^{h} (8.509)	265.013^{c} (2.180)	180.336^{c} (4.958)	445.887^{a} (4.266)	1182.433^{d} (8.552)	16209.183^{f} (118.312)	1098.600^{e} (9.704)	46.126^{a} (0.198)	1.122^{bcd} (0.025)
	Beech	BL	2.653^{ab} (0.611)	3.127^{d} (0.150)	3.787^{e} (0.080)	7.547^{f} (0.146)	236.660^{c} (3.157)	293.020^{d} (7.537)	279.473^{d} (10.336)	134.193^{a} (5.959)	2104.190^{g} (14.759)	1319.050^{f} (12.915)	12469.847^{c} (158.376)	664.460^{b} (16.795)	48.150^{b} (0.149)	1.255^{d} (0.039)
		BB	2.683^{ab} (0.040)	2.447^{b} (0.050)	3.210^{c} (0.050)	5.327^{a} (0.085)	91.463^{a} (0.774)	99.507^{a} (1.009)	134.747^{e} (1.778)	200.447^{d} (5.103)	568.193^{b} (3.345)	835.100^{a} (27.261)	12089.513^{b} (100.934)	995.250^{d} (7.177)	50.894^{f} (0.223)	0.583^{a} (0.039)
		Other	2.390^{ab} (0.275)	4.840^{g} (0.026)	6.603^{h} (0.049)	12.697^{i} (0.063)	701.943^{f} (10.041)	921.780^{g} (4.240)	418.917^{f} (2.732)	161.920^{b} (1.470)	1935.177^{h} (23.402)	1583.483^{i} (11.311)	13169.707^{d} (113.049)	830.007^{c} (13.310)	47.952^{b} (0.112)	1.740^{f} (0.020)
	Oak-Beech	OL	4.083^{ab} (2.581)	2.847^{c} (0.015)	7.000^{i} (0.085)	5.840^{c} (0.017)	239.533^{c} (7.347)	266.673^{c} (4.346)	201.633^{g} (3.171)	160.400^{b} (2.969)	1099.740^{e} (4.935)	1482.307^{h} (23.959)	14209.070^{e} (185.166)	590.707^{a} (15.649)	48.504^{c} (0.298)	0.989^{b} (0.015)
		BL	4.413^{b} (2.622)	3.557^{e} (0.049)	5.470^{f} (0.070)	6.567^{d} (0.035)	234.790^{c} (2.249)	292.213^{d} (2.738)	238.410^{h} (6.094)	134.903^{a} (7.433)	1431.797^{f} (18.747)	1270.583^{e} (7.653)	11486.900^{a} (129.797)	575.870^{a} (9.000)	48.482^{c} (0.194)	1.026^{bc} (0.011)
		B	3.727^{ab} (0.942)	2.937^{c} (0.096)	3.490^{d} (0.010)	6.550^{d} (0.034)	91.817^{a} (5.055)	103.653^{a} (1.018)	143.677^{i} (0.092)	202.310^{de} (1.370)	626.530^{c} (6.816)	1095.240^{c} (2.541)	17148.040^{h} (282.007)	1088.663^{e} (12.068)	49.571^{e} (0.099)	0.602^{a} (0.042)
		Other	3.090^{ab} (0.425)	8.203^{i} (0.083)	6.407^{g} (0.047)	10.663^{g} (0.015)	640.013^{e} (4.061)	738.090^{f} (11.518)	300.960^{i} (5.099)	133.633^{a} (0.532)	986.160^{d} (2.327)	1100.883^{c} (7.336)	12093.560^{b} (63.219)	680.713^{b} (5.504)	48.753^{cd} (0.074)	1.147^{cd} (0.022)

Within a column, means with a different letter are significantly different at α=0.05 level.
OL:Oak Leaves, OB: Oak Branches, BL: Beech Leaves, BB: Beech Branches, B: Branches. Comp.: Components

Table 5. Results of ANOVA of mean elements contents in areas according to annuals Mean (SD).
Tablo 5. Yıllara göre alanların ortalama element içeriklerine ait ANOVA sonuçları.

Time	Area	Zn (mg kg^{-1})	Pb (mg kg^{-1})	Ni (mg kg^{-1})	Cu (mg kg^{-1})	Al (mg kg^{-1})	Fe (mg kg^{-1})	P (mg kg^{-1}))	Na (mg kg^{-1})	Mn (mg kg^{-1})	Mg (mg kg^{-1})	Ca (mg kg^{-1})	K (mg kg^{-1})	C (%)	N (%)
2009	Oak	5.418^{a} (1.017)	2.168^{a} (1.471)	2.413^{a} (0.673)	5.263^{a} (0.780)	98.058^{a} (18.025)	110.587^{a} (18.294)	184.691^{a} (38.376)	213.604^{a} (12.423)	790.804^{a} (308.026)	1288.141^{a} (271.471)	12701.67^{a} (2493.86)	2104.347^{a} (699.165)	48.592^{a} (0.287)	0.890^{a} (0.231)
	Beech	9.343^{a} (5.898)	1.971^{a} (0.775)	3.947^{ab} (0.705)	5.412^{a} (1.164)	88.466^{a} (20.638)	102.33^{a} (27.767)	157.518^{a} (27.056)	188.631^{a} (25.351)	1214.136^{a} (575.058)	1315.976^{a} (362.853)	11898.59^{a} (1067.56)	1523.166^{b} (167.352)	48.223^{a} (0.478)	0.769^{a} (0.165)
	Oak-Beech	7.075^{a} (4.264)	3.093^{a} (1.163)	6.066^{b} (2.660)	5.057^{a} (0.934)	168.059^{a} (45.332)	172.769^{a} (139.839)	153.649^{a} (52.992)	187.882^{a} (42.208)	1015.219^{a} (578.331)	1185.305^{a} (400.403)	16330.83^{a} (7022.62)	1196.033^{b} (509.181)	48.727^{a} (0.874)	0.725^{a} (0.136)
2010	Oak	7.340^{a} (5.034)	2.290^{a} (1.401)	3.491^{a} (1.019)	6.064^{a} (0.699)	223.929^{a} (123.174)	280.804^{a} (169.438)	199.031^{ab} (53.235)	213.966^{a} (26.576)	393.621^{a} (234.025)	1063.579^{a} (318.993)	12831.11^{a} (4191.39)	2064.877^{a} (935.739)	47.859^{a} (1.369)	0.793^{a} (0.226)
	Beech	6.928^{a} (2.025)	2.450^{a} (0.622)	4.548^{a} (1.335)	6.011^{a} (2.261)	215.181^{a} (125.886)	251.790^{a} (152.757)	161.481^{a} (85.316)	212.802^{a} (33.887)	1178.348^{b} (685.659)	1123.307^{a} (431.160)	13348.78^{a} (1798.02)	1144.310^{b} (383.370)	47.646^{a} (0.516)	0.664^{a} (0.332)
	Oak-Beech	9.040^{a} (4.994)	3.214^{a} (1.350)	6.357^{b} (1.797)	6.727^{a} (1.742)	406.694^{a} (430.030)	292.896^{a} (185.275)	230.741^{b} (66.095)	233.463^{a} (26.026)	1206.718^{b} (538.664)	1335.488^{a} (342.192)	13665.21^{a} (1686.30)	1491.127^{ab} (577.982)	46.939^{a} (1.358)	1.156^{b} (0.182)
2011	Oak	5.458^{b} (3.871)	4.608^{a} (2.504)	3.739^{a} (2.250)	7.933^{a} (2.335)	564.480^{a} (455.478)	593.362^{a} (497.855)	197.724^{a} (51.647)	197.281^{a} (13.847)	487.350^{a} (62.854)	1176.618^{a} (217.911)	16344.10^{a} (374.27)	1300.660^{a} (176.780)	48.216^{a} (1.601)	1.076^{a} (0.388)
	Beech	2.576^{a} (0.363)	3.471^{a} (1.071)	4.533^{a} (1.574)	8.523^{a} (3.275)	343.356^{a} (276.242)	438.102^{a} (372.335)	277.712^{b} (123.175)	165.520^{b} (29.090)	1535.853^{b} (729.558)	1245.878^{a} (329.068)	12576.35^{b} (487.00)	829.906^{b} (143.681)	48.998^{a} (1.431)	1.192^{a} (0.504)
	Oak-Beech	3.828^{ab} (1.708)	4.385^{a} (2.320)	5.591^{a} (1.390)	7.405^{a} (1.988)	301.538^{a} (213.360)	350.157^{a} (245.887)	221.170^{ab} (59.770)	157.811^{b} (29.265)	1036.057^{c} (300.523)	1237.253^{a} (165.465)	13734.39^{b} (2318.59)	733.988^{b} (218.152)	48.827^{a} (0.489)	0.941^{a} (0.214)

Within a column, means with a different letter are significantly different at α=0.05 level.

Table 6. Nutrient elements amounts of litterfall in hectare
Tablo 6. Ölü örtü bileşenlerindeki hektardaki besin elementi miktarları

Year	Stand		Litter kg ha^{-1}	Zn g ha^{-1}	Pb g ha^{-1}	Ni g ha^{-1}	Cu g ha^{-1}	Al kg ha^{-1}	Fe kg ha^{-1}	P kg ha^{-1}	Na kg ha^{-1}	Mn kg ha^{-1}	Mg kg ha^{-1}	Ca kg ha^{-1}	K kg ha^{-1}	C kg ha^{-1}	N kg ha^{-1}
2009	Oak	**L**	3247.1	21.54	5.66	10.78	15.83	0.37	0.44	0.59	0.68	2.44	5.02	44.22	3.98	1573.28	35.79
		B	216.4	0.99	0.87	0.42	1.36	0.02	0.02	0.03	0.05	0.10	0.20	3.25	0.49	104.69	1.28
		Other	51.1	0.26	0.04	0.10	0.24	0.01	0.01	0.01	0.01	0.06	0.07	0.48	0.14	25.01	0.50
		Total	**3514.6**	**22.79**	**6.57**	**11.3**	**17.43**	**0.4**	**0.47**	**0.63**	**0.74**	**2.6**	**5.29**	**47.95**	**4.61**	**1702.98**	**37.57**
	Beech	**L**	3185.4	42.48	4.42	10.40	13.61	0.32	0.42	0.44	0.60	5.30	4.43	33.41	4.66	1530.86	28.14
		B	118.8	1.47	0.36	0.29	0.82	0.01	0.01	0.02	0.02	0.05	0.10	1.48	0.21	58.02	0.65
		Other	668.8	1.55	1.03	4.12	3.39	0.07	0.07	0.09	0.15	1.02	1.13	8.53	0.92	319.52	5.84
		Total	**3973**	**45.5**	**5.81**	**14.81**	**17.82**	**0.4**	**0.5**	**0.55**	**0.77**	**6.37**	**5.66**	**43.42**	**5.79**	**1908.4**	**34.63**
	Oak-Beech	**OL**	1504.3	11.44	2.57	12.51	6.01	0.15	0.16	0.23	0.25	2.01	2.03	14.52	1.34	745.28	10.26
		BL	1926.1	24.98	5.34	16.90	10.15	0.78	0.77	0.38	0.42	3.34	3.23	21.14	2.50	920.96	17.40
		B	98.3	0.33	0.30	0.43	0.63	0.01	0.01	0.02	0.02	0.07	0.11	1.78	0.19	48.65	0.75
		Other	81.5	0.35	0.39	0.23	0.37	0.01	0.01	0.01	0.01	0.03	0.05	2.16	0.05	39.16	0.45
		Total	**3610.2**	**37.1**	**8.6**	**30.07**	**17.16**	**0.95**	**0.95**	**0.64**	**0.7**	**5.45**	**5.42**	**39.6**	**4.08**	**1754.05**	**28.86**
2010	Meşe	**L**	4003.8	19.14	7.64	17.59	23.77	0.72	0.89	0.78	0.98	2.78	5.95	63.59	5.46	1937.98	42.89
		B	592.3	8.04	2.40	1.28	4.10	0.06	0.07	0.08	0.13	0.19	0.48	9.10	0.90	290.67	3.28
		Other	112.3	0.41	0.10	0.44	0.60	0.04	0.06	0.03	0.02	0.02	0.10	0.81	0.37	51.77	0.85
		Total	**4708.4**	**27.59**	**10.14**	**19.31**	**28.47**	**0.82**	**1.02**	**0.89**	**1.13**	**2.99**	**6.53**	**73.5**	**6.73**	**2280.42**	**47.02**
	Oak	**L**	2702.7	25.60	4.89	10.63	14.73	0.48	0.55	0.52	0.58	5.19	3.85	35.72	3.00	1274.81	22.55
		B	771.8	4.55	1.80	2.63	2.88	0.07	0.08	0.04	0.13	0.27	0.42	8.75	0.56	372.82	1.77
		Other	2686.2	14.55	8.64	16.92	23.80	1.01	1.20	0.65	0.67	3.42	3.75	41.60	4.31	1275.07	24.94
		Total	**6160.7**	**44.7**	**15.33**	**30.18**	**41.41**	**1.56**	**1.83**	**1.21**	**1.38**	**8.88**	**8.02**	**86.07**	**7.87**	**2922.7**	**49.26**
	Beech	**OL**	1591.7	7.40	2.72	14.27	9.06	0.28	0.32	0.34	0.33	2.50	2.67	22.45	1.80	749.65	19.50
		BL	2032.4	25.79	4.39	13.38	10.17	0.44	0.53	0.45	0.43	3.70	3.27	22.85	2.07	934.06	25.30
		B	1056.7	14.45	4.65	4.50	7.21	0.12	0.13	0.17	0.27	0.56	0.93	16.64	1.47	505.73	9.12
		Other	1862.5	9.58	8.55	10.47	17.48	2.08	1.10	0.62	0.48	1.69	2.19	25.27	4.51	872.48	24.12
		Total	**6543.3**	**57.22**	**20.31**	**42.62**	**43.92**	**2.92**	**2.08**	**1.58**	**1.51**	**8.45**	**9.06**	**87.21**	**9.85**	**3061.92**	**78.04**

L: Leaves, B: Branches, OL: Oak Leaves, BL: Beech Leaves

Table 6. Nutrient elements amounts of litterfall in hectare (Continued)
Tablo 6. Ölü örtü bileşenlerindeki hektardaki besin elementi miktarları (Devamı)

			Litter kg ha^{-1}	Zn g ha^{-1}	Pb g ha^{-1}	Ni g ha^{-1}	Cu g ha^{-1}	Al kg ha^{-1}	Fe kg ha^{-1}	P kg ha^{-1}	Na kg ha^{-1}	Mn kg ha^{-1}	Mg kg ha^{-1}	Ca kg ha^{-1}	K kg ha^{-1}	C kg ha^{-1}	N kg ha^{-1}
2011	Oak	**L**	2955.1	4.31	6.07	8.36	16.69	0.95	0.90	0.52	0.62	1.69	4.21	49.55	3.83	1446.09	43.72
		B	505	2.45	2.04	0.87	3.66	0.10	0.11	0.08	0.10	0.22	0.47	8.11	0.76	250.41	3.18
		Other	158	1.59	1.22	1.05	1.72	0.18	0.20	0.04	0.03	0.07	0.19	2.56	0.17	72.88	1.77
		Total	**3618.1**	**8.35**	**9.33**	**10.28**	**22.07**	**1.23**	**1.21**	**0.64**	**0.75**	**1.98**	**4.87**	**60.22**	**4.76**	**1769.38**	**48.67**
	Beech	**L**	2342.3	6.22	7.33	8.86	17.67	0.55	0.69	0.65	0.31	4.93	3.09	29.21	1.56	1127.83	29.39
		B	165.8	0.45	0.41	0.53	0.88	0.02	0.02	0.02	0.03	0.09	0.14	2.00	0.17	84.38	0.97
		Other	1094.1	2.62	5.29	7.22	13.89	0.77	1.01	0.46	0.18	2.12	1.73	14.41	0.91	524.64	19.04
		Total	**3602.2**	**9.29**	**13.03**	**16.61**	**32.44**	**1.34**	**1.72**	**1.13**	**0.52**	**7.14**	**4.96**	**45.62**	**2.64**	**1736.85**	**49.4**
	Oak-Beech	**OL**	1162.7	4.75	3.31	8.14	6.79	0.28	0.31	0.23	0.19	1.28	1.72	16.52	0.69	563.95	11.50
		BL	1305.4	5.76	4.64	7.14	8.57	0.31	0.38	0.31	0.18	1.87	1.66	14.99	0.75	632.88	13.40
		B	260.2	0.97	0.76	0.91	1.70	0.02	0.03	0.04	0.05	0.16	0.28	4.46	0.28	128.98	1.57
		Other	499.4	1.54	4.10	3.20	5.33	0.32	0.37	0.15	0.07	0.49	0.55	6.04	0.34	243.47	5.73
		Total	**3227.7**	**13.02**	**12.81**	**19.39**	**22.39**	**0.93**	**1.09**	**0.73**	**0.49**	**3.8**	**4.21**	**42.01**	**2.06**	**1569.28**	**32.2**
Mean		**Oak**	**3947,03**	**19.58**	**8.68**	**13.63**	**22.66**	**0.82**	**0.90**	**0.72**	**0.87**	**2.52**	**5.56**	**60.56**	**5.37**	**1917.59**	**44.42**
		Beech	**4578,63**	**33.16**	**11.39**	**20.53**	**30.56**	**1.10**	**1.35**	**0.96**	**0.89**	**7.46**	**6.21**	**58.37**	**5.43**	**2189.32**	**44.43**
		Oak-Beech	**3901,65**	**35.78**	**13.91**	**30.69**	**27.82**	**1.60**	**1.37**	**0.98**	**0.90**	**5.90**	**6.23**	**56.27**	**5.33**	**2128.42**	**46.37**

L: Leaves, B: Branches, OL: Oak Leaves, BL: Beech Leaves

Mineral nutrients and C content in forest ecosystems are substantially supplied from litterfall. Therefore, it is important to measure, model and estimate of litterfall as an important parameter for global carbon cycle and carbon accumulation (Liski et al., 2005). Moreover, litterfall is one of the important components of net primary production and very important for phonological observations (Hansen et al., 2009).

In this study, the average amount of litterfall in the oak and beech stands was found to be 3947 and 4578 (kg ha^{-1}), respectively. The average amount of litterfall by years was 3514-4708 kg ha^{-1} in the oak stand, 3602-6160 kg ha^{-1} in the beech stand and 3227-6543 kg ha^{-1} in the oak-beech mixed stand. The highest amount of litterfall in all of the three sites was measured in 2010 because it is rich seeds year.

Some of the studies conducted in similar sites are also consistent with our findings. Irmak and Çepel (1968) reported that the average amount of litterfall in the oak and beech stands in the Belgrad Forest was 3546 kg ha^{-1} and 3712 kg ha^{-1}, respectively. Carlisle et al. (1966) reported that the average amount of total litterfall from *Quercus petraea* (from 1961 to 1964) was 2206 kg ha^{-1}. Augusto et al. (2002) found that the annual litterfall amount in the temperate forests in Europe was 3.5 t ha^{-1} - 4.0 t ha^{-1} in general. Trap et al. (2011) reported that the annual litterfall amount was 2.58 t ha^{-1} in *Fagus sylvatica* forests in France, while Kavvadias et al. (2001) found the litterfall amount of the same species as 4.0 t ha^{-1} in Greece. The amount of litterfall may vary across different sites and biomes. Pandey et al. (2007) found that the annual litterfall in semi-tropical *Quercus serrata* forest was 4.19 and 5.47 t ha^{-1}, while Tateno et al. (2007) found the annual litterfall amount was 4.20 t ha^{-1} in *Quercus liaotungensis* forest in China.

In their comprehensive study, Bray and Gorham (1964) and Vogt et al. (1986) stated that there was not a major difference between the tree species with respect to litterfall. There are significant differences depending on the climate. Liuet al. (2004) reported that the total litterfall in the temperate forests was higher in broad-leaved species than in the coniferous species while this is to the contrary in the boreal zones. In this study, no major difference was either found between the oak and beech trees in the same habitat with respect to litterfall.

Collection of different plant parts in the litter is important to determine the amount of nutrients supplied by each part to the soil system. Litterfall has become an important parameter recently in monitoring global climate change in addition to the plant flowering and foliation used for phonological observation (Hansen et al., 2009). Almost 80% of the net primary production is supplied back to the ecosystem by means of litterfall (Meentemeyer et al., 1982; Kassnacht and Gower, 1997). Therefore, the amount of litterfall is important for the health of the ecosystem. There are studies that focused on determining the total amount of litterfall with the equations based on the amount of different plant parts in the litterfall (Meentemeyer et al., 1982; Hansen et al., 2009). However, the amount of litter varies significantly across the ecosystems. Previous studies showed that the leaf litter accounted for 75-85% of the total litterfall (Bray and Gorham, 1964; Meentemeyer et al., 1982). In this study, the amount of litterfall ranged from 81% to 92% in the oak stand across the years. Although it fell to 50% in 2010, when is rich seeds year, in the oak-beech fixed stand, there was no significant difference between the years in terms of mass.

There were temporal and spatial statistical differences between the element concentrations of litterfall components. The highest element concentration was found in C, Ca, Mg, K and Mn, respectively in the leaves of the oak trees while it was in C, Ca, Mn, Mg and K in the beech stands. Beech is capable of effectively using a substantial amount of nutrients (Mn, Mg, Ca) carried over biologically from deep soils to the active organic layer by means of mycorrhiza and its roots (Meier et al., 2005). Langenbruch et al. (2012) conducted a study in beech stands and found that the Mn content of the leaves in the litterfall had a negative association with the pH of the top soil. In our study, the amount of Mn in the leaves of the beech trees was higher than the amount of Mg and K, which might be associated with the low pH of the soil as mentioned above. C, Ca, K and Mg had the highest concentration in the branches and other parts. Similar to the findings of our study, Shin et al. (2011) found that K, Ca and Mg had the highest concentration in the leaves of the oak trees while Ca and K had the highest concentration in the branches and barks. Mun et al. (2007) found the highest density in K, Ca and Mg in the leaves, and in K, Ca and Mg in the branches and barks. In another similar study, Hansen et al. (2009) found that K, Ca and Mg had the highest concentration in the leaves in the beech and oak stands. Furthermore, K, Ca and Mg were found to have the highest amount in the branches of oak and beech trees. In another study conducted in the mixed stands, Ca and Mg as nutrients reaching the soil surface by litterfall were found to be high however, this was to the contrary for K (Nordén, 1994). The reason why Ca, Mg and K has the highest concentration in the leaves is because the nutrients are carried as N≈P>K>Mg>Ca throughout the senescence process of leaves (Smith ve Shortle, 1996; Martin et al., 1998; Meerts, 2002). Furthermore, K, N, P and Na are highly mobile elements in an ecosystem (Santa Regina et al., 1997). Apart from these elements, Pb, Ni, Cu, Zn, Al, Fe and Mn were found to have the lowest concentration in our study.

In our study, the highest element concentration was found in the leaves while the lowest was found in the branches, in general. In other studies, the percentage of total nutrient input through litterfall was found to be 75-85% in leaves, and 10-35% in branches and other parts (including flower, fruit and seed) (Klinge and Rodrigues, 1968; Bernhard-Reversat, 1972; Rawat and Singh, 1989). Similarly, Pandey and Singh (1981) reported that the nutrient input in the oak-coniferous mixed forests was 80-83% through leaves, and 17-20% through branches. As for the element concentration of the total litterfall in our study, there were temporally and spatially statistical differences, while there were statistically significant differences between the element concentrations of Zn and Ca in the oak leaves across the years. For the beech leaves, however, there were statistical differences between the element concentrations of Pb, Mn, Mg, Cu, Al, Na and K across the years. Contrary to the data obtained, Hansen et al. (2009) found that there was no significant difference between five different tree species with respect to the nutrient density of the leaves as litterfall component. This may vary due to the different effects of environmental factors (soil nutrients, precipitation and temperature differences).

An overall assessment of the nutrient content revealed that the total order of the nutrients was C>Ca>N>Mg>K>Mn>P, while on average element concentrations (kg $ha^{-1}y^{-1}$) was 1917.59 for C, 44.42 for N, 5.37 for K, 60.56 for Ca, 5.56 for Mg, 0.72 for P, 2.52 for Mn, 0.87 for Na, 0.82 for Al, 0.90 for Fe in the oak stand, whereas 2189.32 for C, 44.43 for N, 5.43 for K, 58.37 for Ca, 6.21 for Mg, 0.96 for P, 7.46 for Mn, 0.89 for Na, 1.10 for Al, 1,35 for Fe in the beech stand, and 2128.42 for C, 46.37 for N, 5.33 for K, 56.27 for Ca, 6.23 for Mg, 0.98 for P, 5.90 for Mn, 0.90 for Na, 1.60 for Al, 1.37 for Fe in the oak-beech mixed stand. In a study conducted by Hansen et al. (2009), they found that the total nutrient amount supplied by total litterfall in the beech stands was 1397 kg $ha^{-1}y^{-1}$ for C, 39 kg $ha^{-1}y^{-1}$ for N, 2.1 kg $ha^{-1}y^{-1}$ for P, 7.1 kg $ha^{-1}y^{-1}$ for K, 23 kg $ha^{-1}y^{-1}$ for Ca, 3.2 kg $ha^{-1}y^{-1}$ for Mg, 2.9 kg $ha^{-1}y^{-1}$ for Mn. It was 1611 kg $ha^{-1}y^{-1}$ for C, 55 kg $ha^{-1}y^{-1}$ for N, 3.3 kg $ha^{-1}y^{-1}$ for P, 9.8 kg $ha^{-1}y^{-1}$ for K, 26 kg $ha^{-1}y^{-1}$ for Ca, 4.8 kg $ha^{-1}y^{-1}$ for Mg, 4.2 kg $ha^{-1}y^{-1}$ for Mn in the oak stands. In another study, Pedersen and Bille-Hansen (1999) found the average nutrient amount through litterfall in the beech stands for six years as 45 kg $ha^{-1}y^{-1}$ for N, 1.9 kg $ha^{-1}y^{-1}$ for P, 10.5 kg $ha^{-1}y^{-1}$ for K, 18 kg $ha^{-1}y^{-1}$ for Ca, 3.5 kg $ha^{-1}y^{-1}$ for Mg, 2.7 kg $ha^{-1}y^{-1}$ for Na, 0.6 kg $ha^{-1}y^{-1}$ for A1, 0.3 kg $ha^{-1}y^{-1}$ for Fe. Similarly, Shin *ve ark.* (2011) found the average nutrient amount through litterfall in the oak stands for four years as 53.42 kg $ha^{-1}y^{-1}$ for N, 3.76 kg $ha^{-1}y^{-1}$ for P, 17.79 kg $ha^{-1}y^{-1}$ for K, 17.15 kg $ha^{-1}y^{-1}$ for Ca, 5.76 kg $ha^{-1}y^{-1}$ for Mg. When the results of our study are compared with those of the other studies, it appears that other elements except K, P and Na had higher amounts. This difference might be due to the different number of trees per hectare, crown closure and age (Mun et al., 2007). Furthermore, the results of our study demonstrate that the nutrient input in beech stands and oak-beech mixed stands was similar. It can be suggested that this was due to higher amount of beech leaves in the litterfall components in the oak-beech stands compared to the amount of oak leaves.

4. CONCLUSION

The highest litterfall amount was found in 2010 in our study in all of the three sites. Therefore, the amount of nutrients in the litterfall in the oak-beech mixed stand was remarkably higher in 2010 as it was the rich seeds year. Moreover, the nutrient input in the oak-beech mixed stands was similar to the input in the beech stands. This can be associated with the dominant species in the mixture. In this study, the amount of micro elements was also determined in addition to the macro nutrients. According to the data of our study, the density was in general found to be high in C>Ca>N>Mg>K>Mn>P>Al>Fe>Na>Zn>Cu>Ni>Pb, respectively.

Future studies to be conducted on litter decomposition, soil nutrients, nutrients in the biomass and litterfall will ensure better understanding of the nutrient flows in the ecosystem. It is hoped that the results of our study will lay the basis for such future studies.

ACKNOWLEDGEMENT

We would like to thank Prof. Ender Makineci and Prof. Doğanay Tolunay for their scientific and moral support in the performance of this study and also for their assistance in the laboratory analyses.

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