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INFLUENCE OF DIFFERENT PARENT MATERIALS ON LITTER DECOMPOSITION IN THE EAST MEDITERRANEAN REGION

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Abstract

Litter decomposition is the fundamental pathway for the turn of carbon, nitrogen and nutrients to terrestrial ecosystem and strongly influenced by climatic variables, litter quality and microbial activity. This study was carried out to investigate the effects of two different parent materials (conglomerate and marl) on litter decomposition and the relationships between litter quality and decomposition rate of *Pinus pinea* L. and *Ceratonia siliqua* L. in the East Mediterranean Region of Turkey. Fresh fallen litters from *P. pinea* and *C. siliqua* plants were determined contents of C, N, P, lignin and cellulose. The litter bag method was used to determine their mass loss in the sampling area for 544 days. Litter mass loss in decomposition varied in the following order: $Ceratonia_{marl}$>$Ceratonia_{cong}$>$Pinus_{cong}$>$Pinus_{marl}$. There were no significant differences among the samples in terms of lignin contents of initial litter while cellulose content was only statistically significant between $Pinus_{cong}$ and $Ceratonia_{cong}$ ($p<0.05$). These results suggested that litter decomposition is affected from different parent materials (conglomerate and marl) and plant diversity.

Introduction

Litter decomposition has an effective function in terrestrial ecosystems by acting as an energy source for soil microorganisms. Physical**,** chemical and biological characters of the environment control litter decomposition in the soil (Sarıyıldız *et al*., 2005). Both temperature and moisture have strong impacts on the chemical characteristics of litter decomposition as well as the yield of microbial activity (Keeler *et al*., 2009). Studies on plant litter dynamics have showed that controlling factors on decomposition rates and nutrient cycling are correlated with climactic conditions (Cusack *et al*., 2009), whereas at a small scale, the chemical compounds of the litter such as carbon:nitrogen ratio, lignin contents, lignin:nitrogen ratio and lignin:cellulose in the forest floor (Sarıyıldız *et al*., 2005; Talbot & Treseder, 2012).

The decomposition of litter is a basic biogeochemical process, due to its role in the carbon sequestration, as well as the nutrient recycling between soil and plant (Peng *et al*., 2014). The varieties at the litter decomposition rates possess major impacts on mechanisms of ecosystems (Fang *et al*., 2007). The plant species is an effective factor on the chemical composition of the litter (Jose & Domigo, 2000) but there is also proof in a literature that plants can show important intra-specific variations in litter components in relation to different soil conditions, and these variations can affect decomposition rates.

The litter decomposition, release of essential nutrients for plant growth, maintenance of soil microbial dynamics and biogeochemical changes in the soil contribute to the soil organic carbon and nitrogen contents.

The most abundant compounds of litter are lignin and cellulose which are slowly decomposed (Sarıyıldız *et al*., 2005). High lignin concentrations in the litter have a detractive influence on decomposition stage. Especially, when related with high nitrogen content, because fresh and consistent complexes are constituted (Peng *et al*., 2014).

Parent material, topography, vegetation and climate are affecting factors the formation, composition and types of the soils. Parent material, which can control soil processes, is major cause of variation in soil (Aka Sagliker & Darici, 2007). There were some studies about effects of different parent materials on litter decomposition and nutrient dynamics (Kooijman & Smit, 2009). The identical plants growing on soil derived from various parent materials can be unlike litter decomposition. Plants showing the best parent material difference is very important.

Many studies has been conducted on different ecophysiological aspects of *Pinus pinea* L. (Pinaceae) and *Ceratonia siliqua* L. (Fabaceae), the two typical representatives of the mediterranean climate (Ozturk *et al*., 2010; Ouzounidou *et al.,* 2012), but very scanty information is variable on the leaf litter decomposition rate of naturally growing stands of these plants species on marl and conglomerate soils. The objective of the present study was to determine the effects of soils derived from two different parent materials (marl and conglomerate) on litter decomposition, litter quality and decomposition rate in the East Mediterranean Region of Turkey.

Materials and Methods

The experiment was carried out in two sites; with two different parent materials in Adana, Turkey. This region is under Eastern Meditteranean climate conditions, which is characterized by annual precipitation of 663 mm and annual temperature of 18.7°C for 57 years. *Pinus pinea* L., and *Ceratonia siliqua* L. were chosen for this study. *P. pinea* sites have marl parent material in Menekşe village (37°0.3′N, 35°22′E; altitude 153 m) and conglomerate parent material in Çukurova University campus (37°0.3′N, 35°21′E; altitude 145 m) while sites of *C. siliqua* having both parent materials are located in the same campus.

Soil and litter samples from these two evergreen species were collected every three months between March 2012 and October 2013. Fresh fallen leaves and needles of three plants were taken to represent a sample for each plant species.

In order to determine decomposition of litter in the plants the litter bag method was used.

The litter bags of 1 mm acrylic-coated mesh were 20×20 cm. This mesh size was enough to obstruct the loss of litter fractions and permits for activities of soil microorganisms and the input of small soil animals into the bag . 20 g of litter were air-dried and then placed into the each bag. They were buried on the upper mineral soil layer belonging to the plants (0 cm). Litter bags were collected after 103, 207, 318, 415, 468 and 544 days. The bags were brought to the laboratory. The each bag was cleaned by a brush and weighed. The litter from each bag were oven dried at 70°C to a constant weight and each sample was weighted separately.

The Van Soest method was used to specify neutral detergent fiber (NDF), acid detergent fiber (ADF) and cellulose with a ANKOM 200/220 fiber analyzer (Van Soest & Robertson, 1985). Litter of each plant was weighted in F57 filter bags (~1 g). Cellulose was determined by burning at 600°C for 6 h. The contents of lignin (ADF-Cellulose), cellulose (ADF- Lignin) and non-structural components (100-NDF) were calculated.

The texture of soil was estimated by Bouyoucos hydrometer (1951). The soil pH was determined in mud saturated with distilled water (1:2.5) using WTW Inolab 720 pH meter (Jackson, 1958). $CaCO_3$ content of soil with a Scheibler calcimeter (Allison & Moddie, 1965). The contents of organic carbon and total nitrogen of samples (%) were determined by the Anne and Kjeldahl methods, respectively (Duchaufour, 1970). The content of phosphorus in the soil was analyzed by the method of Olsen (Olsen *et al*. 1954). The exponential model for each plant according to Olson (1963) was employed to calculate the decomposition constant (*k*).

Data were tested with variance analysis for each parameter of the two parent materials (marl and conglomerate) and litter chemical compositions of *P. pinea* and *C. siliqua*. Obtained data from this study were analysed statistically using Tukey's test in SPSS 17. Results were given means and standard errors as significance level at $p<0.05$.

Results

Pinus and *Ceratonia* soils derived from conglomerate and marl parent materials showed sandy loam texture (Table 1). There were no significant differences among all soil samples in terms of soil sand content (%). Clay content (%) of *Pinus* was statistically significant between the two parent materials ($p<0.05$), whereas the soils of *Ceratonia* were not different. There were no significant differences between the soils of *Pinus* and *Ceratonia* in terms of loam content (%). Field capacity (%) and pH values did not change among all soil samples. PWP ratios (%) too were not different, but was significant between two different parent materials of each plant (Table 1). $CaCO_3$ contents (%) of soils with marl parent material were significantly higher than same two plant soils with conglomerate parent material ($p<0.05$). C contents (%) of marl soils of both *Pinus* and *Ceratonia* were approximately two times lower than conglomerate soils of the two plants. Different parent materials did not affect N contents of two plants. C/N ratios were different between two parent materials in two plants (Table 1).

Nitrogen, lignin and cellulose contents (%) of initial litter were not significantly varied between the two different parent materials and two plants (Table 2, Figs. 2-3). Carbon content (%) of initial litter was only significant between conglomerate and marl parent materials of *P. pinea* ($p<0.05$). Phosphorus content of marl parent material of both *Pinus* (0.05%) and *Ceratonia* (0.06%) was significantly lower than conglomerate parent material of the two plants (0.11 and 0.08, respectively). NSC content (%) was not different from the point of view of two different parent materials ($p>0.05$) while there were significant differences between two plants ($p<0.05$, Table 2, Figs. 2-3).

Table 1. Physical and chemical characteristics of soils *Pinus pinea* and *Ceratonia siliqua* (FC: Field capacity, PWP: Permanent wilting point).

	Pinus $_{cong}$	***Pinus*** $_{marl}$	***Ceratonia*** $_{cong}$	***Ceratonia*** $_{marl}$
Sand (%)	75.9 ± 0.86a	66.2 ± 6.20a	78.3 ± 1.48a	59.1 ± 7.34a
Clay (%)	15.9 ± 0.05a	13.1 ± 0.57b	3.59 ± 0.22c	4.95 ± 0.85c
Loam (%)	8.28 ± 0.83b	20.7 ± 5.70ab	18.2 ± 1.39ab	35.9 ± 6.92a
Texture type	SL (Sandy loam)			
FC (%)	31.9 ± 1.70a	24.6 ± 1.35a	29.9 ± 3.50a	25.6 ± 0.58a
PWP (%)	25.2 ± 1.02a	14.0 ± 1.76b	25.1 ± 3.16a	13.9 ± 0.28b
pH	7.38 ± 0.03a	7.40 ± 0.01a	7.39 ± 0.01a	7.44 ± 0.04a
$CaCO_3$ (%)	2.84 ± 0.92c	16.6 ± 0.35a	8.95 ± 1.01b	15.6 ± 1.97a
C (%)	2.93 ± 0.25b	1.18 ± 0.04c	4.37 ± 0.49a	2.21 ± 0.15bc
N (%)	0.19 ± 0.02b	0.18 ± 0.01ab	0.23 ± 0.02a	0.23 ± 0.01a
C/N ratio	15.5 ± 1.77a	6.62 ± 0.49b	19.5 ± 0.72a	9.90 ± 0.97b

Mean ± SE, $n = 3$. Different letters denote significant differences between conglomerate and marl parent materials and two plants (*Pinus* and *Ceratonia*), $p<0.05$

Table 2. Chemical composition of initial litter (22 March 2012; NSC: Non-structural components).

	Pinus cong			*Pinus* marl			*Ceratonia* cong			*Ceratonia* marl		
C (%)	61.4	±	2.15a	41.7	±	2.27b	56.5	±	1.86a	53.3	±	0.93a
N (%)	1.14	±	0.11a	1.37	±	0.11a	1.49	±	0.08a	0.94	±	0.00a
P (%)	0.11	±	0.01a	0.05	±	0.00c	0.08	±	0.00b	0.06	±	0.00c
Lignin (%)	9.91	±	1.88a	11.0	±	1.04a	20.4	±	3.24a	16.0	±	2.51a
Cellulose (%)	28.7	±	1.54a	27.2	±	1.45ab	24.4	±	0.96ab	19.7	±	2.81b
NSC (%)	58.1	±	1.14b	62.8	±	1.01b	69.8	±	1.12a	74.7	±	0.98a

Mean ± SE, *n* = 3. Different letters denote significant differences between conglomerate and marl parent materials and two plants (*Pinus* and *Ceratonia*), p<0.05

The highest litter mass loss (%) was in *C. siliqua* growing on marl parent material at the end of 544 days, it was the lowest in *P. pinea* growing on marl parent material (Fig. 1). Litter mass loss in decomposition varied in the following order: $Ceratonia_{marl}$ > $Ceratonia_{cong}$ > $Pinus_{cong}$ > $Pinus_{marl.}$ No differences were observed in conglomerate parent materials in terms of litter mass loss. *P. pinea* growing on marl parent material showed the lowest litter mass loss than the other parent material and plant. There were almost no significance differences between 318^{th} and 468^{th} days in both plants and parent materials. It can be concluded that all litters are not decomposed during 150 days except for *P. pinea* with marl parent material (Fig. 1). The variation in this study using exponential model.

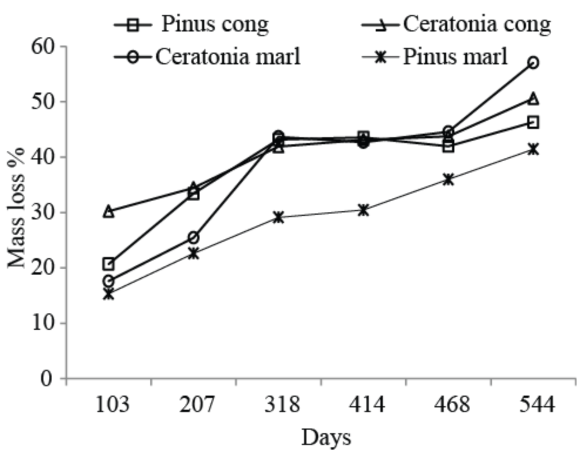

Fig. 1. Litter mass loss (%) of *Pinus pinea* and *Ceratonia siliqua* dependent time (mean ± SE, *n* = 3).

In (X) = ln (X_o) – kt (where X_0 is the initial mass, X is the mass at time t, and k the decay rate ranging from 0.001 to 0.0014, Table 3) has revealed that all samples show medium decomposition rate during 544 days.

Discussion

P. pinea and *C. siliqua* soils derived from conglomerate and marl parent mateials have different physical and chemical traits due to differences both in the parent materials and the plants. C contents (%) of marl soils of both *Pinus* and *Ceratonia* are significantly lower than conglomerate soils of both plants (p<0.05). Different parent materials did not affect N contents of two plants. Kooijman & Smit (2009) found that concentrations of carbon and nitrogen were not changed among soils of beech and hornbean growing on marl and limestone. On the contrary, in soil with basalt parent material contents of carbon, nitrogen, phosphorus and potassium were significantly higher than soil with limestone according to Klemmedson (1994). Aka Sağlıker & Darıcı (2007) reported that carbon and nitrogen amounts of *Pistacia terebinthus* L. soil derived from marl were significantly lower than soil derived from conglomerate while there has been found no difference in the *Pinus brutia* Ten.

Carbon content (%) of initial litter is significant between conglomerate and marl parent materials of *Pinus* (p<0.05). Phosphorus content of marl parent material of both *Pinus* (0.05%) and *Ceratonia* (0.06%) is significantly lower than conglomerate parent material of both plants (0.11 and 0.08, respectively). Plant species and soils with different parent materials affect the carbon and phosphorus contents of initial litter (Aka Sagliker & Darici, 2007). Composition of soil organic matters and variety of soil microorganisms might be influenced by different plant species. Priha *et al*., 2001 reported that the soils of birch (*Betula pendula* Roth.) different from soils of conifers (*Picea abies* L. Karst; *Pinus sylvestris* L.).

Litter mass loss in decomposition varied in the following order at the end of 544 days: $Ceratonia_{marl}$> $Ceratonia_{cong}$> $Pinus_{cong}$> $Pinus_{marl}$. 103-318 days and 468-544 days were significant between in the litter mass loss of *Pinus* and *Ceratonia* (p<0.05). Especially between 103-318 days and 468-544 days in the litter mass loss of *Pinus* and *Ceratonia* (p<0.05). *Ceratonia* litter with marl and conglomerate parent materials showed rapid decomposition as compared with *Pinus* during the sampling time intervals. This may be derived from the variation in plant species and its organic matter quality (Sarıyıldız *et al*., 2005; Keeler *et al*., 2009). This result has also been explained as that both habitat and litters of *Ceratonia* are convenient for fragmentation and decomposition. The differences in the decomposition of litter are correlate with the chemical and constitutional differences between plant species (Jose & Domigo, 2000). Rapid decomposition of *Ceratonia* is because of the presence of easily decomposable and soluble material in *Ceratonia* leaf litter (Kooijman & Smit, 2009).

In forest ecosystem researches, decomposition of litter has a major importance from the point of view of nutrient cycling (Peng *et al*., 2014). Plant production depends on availability of organic matter and cycling of nutrient in the ecosystem. The formation and stabilisation of organic matter in the various systems can also affect soil structure, water-holding capacity and ion exchange. Cusack *et al*. (2009) have also claimed that litter decomposition can be affected by changes in soil conditions within the time. The results obtained from the present study showed that litter decomposition of plants growing on different parent material is different in East Mediterranean Region.

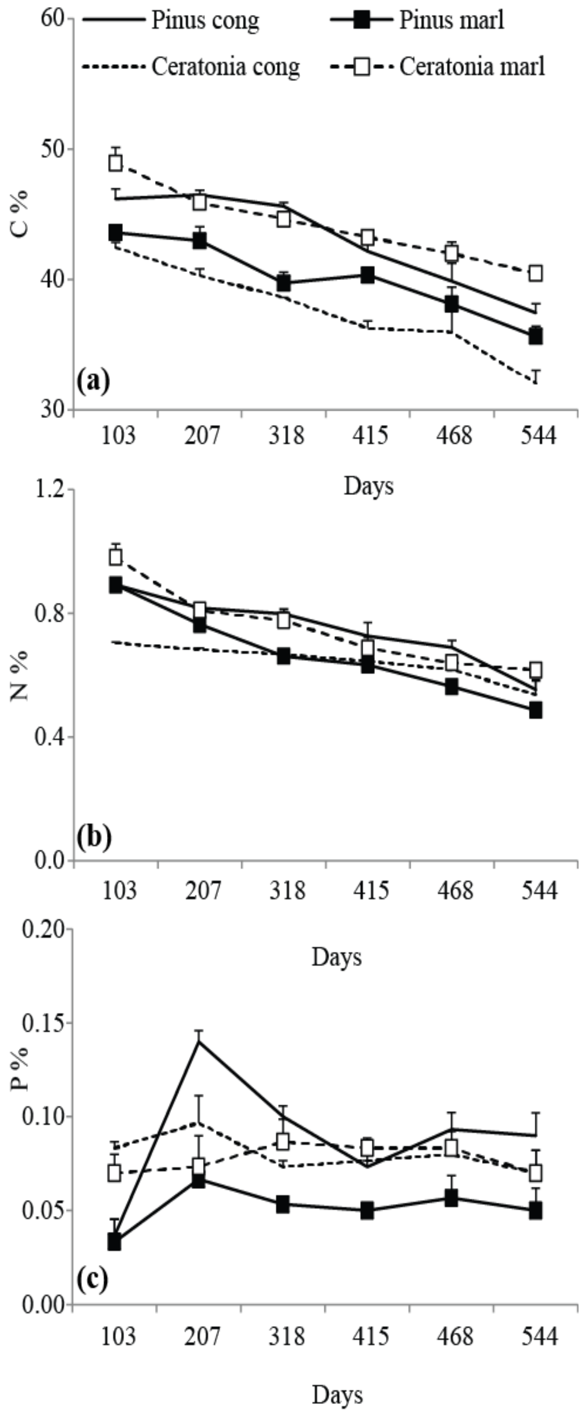

Fig. 2. Carbon (a), nitrogen (b) and phosphorus (c) contents in decomposing litter of *P.pinea* and *C.siliqua* at different parent materials during 544 days (mean ± SE, n = 3; $p<0.05$).

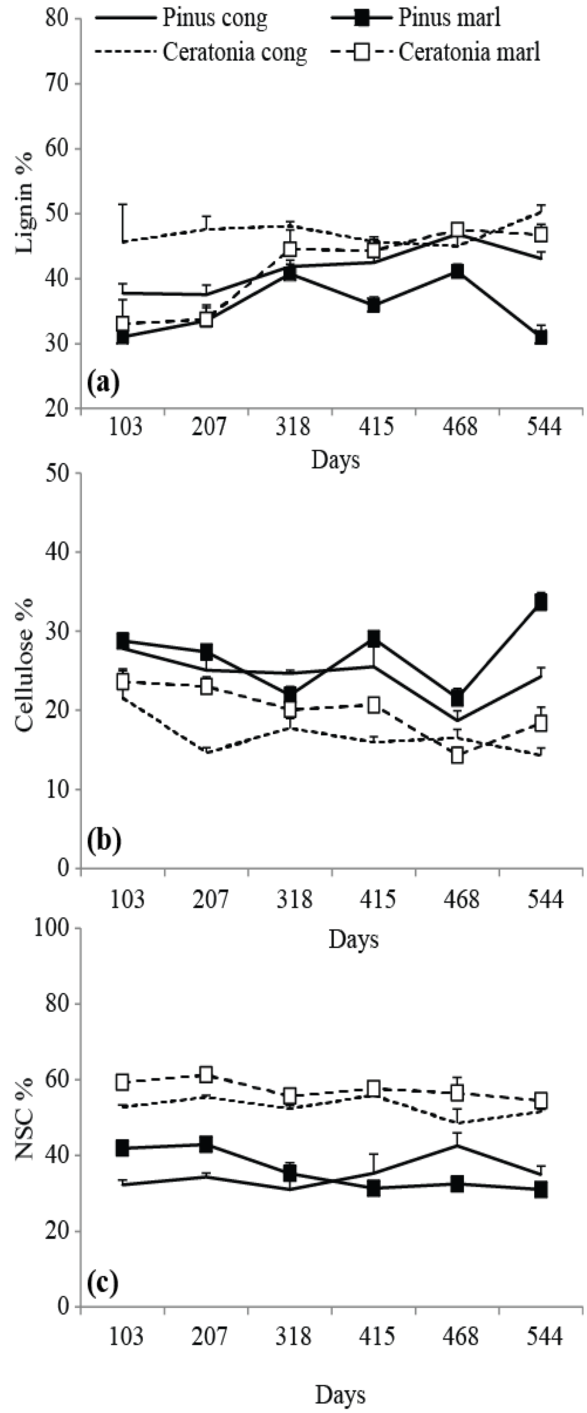

Fig. 3. Lignin (a), cellulose (b) and NSC (c) contents in decomposing litter of *P. pinea* and *C. siliqua* at different parent materials during 544 days (mean ± SE, n = 3; $p<0.05$).

Table 3. Decay rate (k) and adjusted R^2 of the exponential model of decomposing litter *Pinus pinea* and *Ceratonia siliqua* at two parent materials.

Plants	k	R^2
$Pinus_{cong}$	0.001	0.90
$Pinus_{marl}$	0.0008	0.93
$Ceratonia_{cong}$	0.001	0.79
$Ceratonia_{marl}$	0.0014	0.93

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