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# Decomposition rates of legumes and cellulose in a *Pinus halepensis* Mill. forest of Greece after a wildfire

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ABSTRACT: Decomposition of pure cellulose and leaves and stems of leguminous herbs was examined in a Mediterranean Aleppo pine forest 18 months after a severe summer wildfire. Decomposition rates were estimated from the dry mass loss of cellulose and legumes enclosed in fine (0.9 mm) mesh bags. The mean mass loss of cellulose was found to be extremely high (97.1%) from the first sampling date, 45 days after the burial and did not vary considerably among the sampling dates. The mean mass loss of leguminous material was much lower than that of cellulose and appeared a peak 113 days after burial. During almost the whole sampling period, the mean mass loss of cellulose was about two times higher than that of leguminous material and this difference was found to be statistically significant ($p=0.017$). During the post-fire recovery process, the litter of legumes would serve as a direct input of nitrogen in the soil nutrient pools through its relatively slow decomposition. Thus, it is reasonable to conclude that the keystone role of legumes in the post-fire communities is not delineated only in their nitrogen fixing ability but also in their decomposition attributes.

## 1 INTRODUCTION

*Pinus halepensis* Mill. (Aleppo pine) forests are estimated to cover approximately $3 \times 10^6$ ha (Quezel 2000) in the Mediterranean Basin and, therefore, constitute one of the dominant mediterranean-type ecosystems (Arianoutsou 1998). In Greece, Aleppo pine forests cover 371984 ha, which constitute 8.72% of the total forested area (Ministry of Agriculture 1992).

It is long ago accepted that fire is an environmental factor shaping the Mediterranean landscapes. In Greece between the years 1965 to 1990 almost one fifth (~21%) of the registered fire events have burst over *Pinus halepensis* forests, consuming 122,015 ha, which constitute approximately 17% of the total burned areas (Arianoutsou and Ne'eman 2000). Considering the cover of *P. halepensis* forests in Greece, this amount becomes increasingly important. Provided that no secondary disturbance occurs at the burned sites, recovery of these burned ecosystems is taking place following the initial floristic composition process (Kazanis and Arianoutsou in press).

In this recovering process, Leguminosae, one of the richest plant families of the Mediterranean-type ecosystems (Arianoutsou and Thanos 1996), play a significant role (Arianoutsou and Margaris 1981a, Papavassiliou and Arianoutsou 1993, Kazanis and Arianoutsou 1996). Legumes are a dominant component of the biodiversity of recently burned places (Arianoutsou and Thanos 1996, Kazanis and Arianoutsou in press); the percentage of legume taxa is almost doubled immediately after fire (Kazanis and Arianoutsou 1994). Through symbiotic $N_2$ fixation and high-quality litter inputs rich in nitrogen, legumes may compensate N losses in fire's smoke (Arianoutsou and Margaris 1981b) thus increasing nitrogen and other nutrients availability to various growing plant species after the fire event (Kalburtji et al. 1998, Hendricks and Boring 1999).

Despite the abundance and the role of legumes during the early post-fire successional stages, no study dealing with their decomposition rate in burned Mediterranean pine forest has been reported so far. The aim of the current work is the investigation of decomposition rate of leaves and stems of leguminous herbs as well as of pure cellulose in a *Pinus halepensis* forest of Central Greece 18 months after a severe summer wildfire.

## 2 MATERIALS AND METHODS

### 2.1 *Research site*

The fire event took place in a mature *Pinus halepensis* forest in Ag. Stefanos ($38^0$ 09′35′′ N, $23^o$ 52′ 40′′ E) Attica, Greece in July 1993. The site studied was overlying on tertiary deposits and it has a typical Mediterranean climate with mean annual rainfall 457.6 mm and mean annual temperature 16.5$^o$C.

The site was severely burned and no needles remained on the burned pine trunks while microsites with white ashes were scarcely found. In this patch the organic horizon was completely consumed by fire.

Forty-nine legume taxa were identified and their mean density was 28.8 ind.m$^{-2}$. At the end of the first growing season the biomass of herbaceous legumes was 34.1 gm$^{-2}$ and constituted the 34.8% of the total herbaceous biomass and increased significantly at 99.9 gm$^{-2}$ and 45.5% respectively at the end of the second growing season (Papavassiliou 2001).

The study was carried out from December 1994 to October 1995 and six field expeditions were performed according to the scheme: December 1994, January, February, April, May, June, August and October 1995.

### 2.2 *Experimental design*

The decomposition rate was studied by estimating the rate of mass loss of cellulose and leguminous material. Filter paper of high quality, that is pure cellulose, was cut in pieces, oven-dried, weighted, and pieces of approximately 1g dry weight were enclosed in 10x10 cm nylon mesh bags with mesh size of 0.9 mm.

Leaves and stems of legumes were collected from the study site at the end of the first growing season (i.e. spring 1994), were cut in pieces, oven-dried, weighted, and pieces of approximately 1g dry weight were enclosed in 10x10 cm nylon mesh bags with mesh size of 0.9 mm.

Early in December 1994 the litterbags were placed in the field. The bags were placed on the surface of bare ground in a randomized design covering the whole area. Overall, five bags with cellulose and five bags with legumes were collected in each sampling campaign. The bags were placed in plastic envelopes and transported to the laboratory. The filter papers and the leguminous material remaining in the bags were removed from them, oven-dried at 70$^0$C for 48 hrs and incinerated in a muffle furnace at 500$^0$C for 5 hours for the final estimation of the net mass loss (soil free).

Differences in the pattern of mass loss between the cellulose and the leguminous material were detected by Mann-Whitney (U-test) by means of the software package STATISTICA 4.3.

## 3 RESULTS

The mean mass loss of cellulose was found to be extremely high (97.1%) from the first sampling date 45 days after the burial and did not vary considerably among the sampling dates.

The mean mass loss of leguminous material was much lower than that of cellulose and appeared a peak 113 days after burial. During almost the whole sampling period, the mean mass loss of cellulose was about two times higher than that of leguminous material. A statistically significant difference was found in the patterns of mass loss between cellulose and leguminous material (U=7.5, p=0.017).

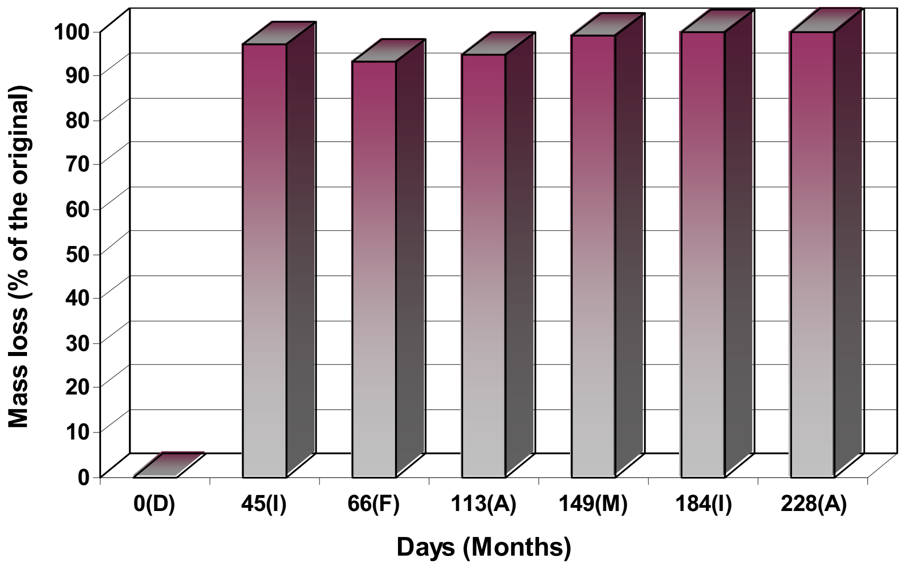


Figure 1. Dry mass loss of cellulose (ash-free) from the mesh bags during the sampling period. Date of burial (day 0 at the diagram): 14/12/1994

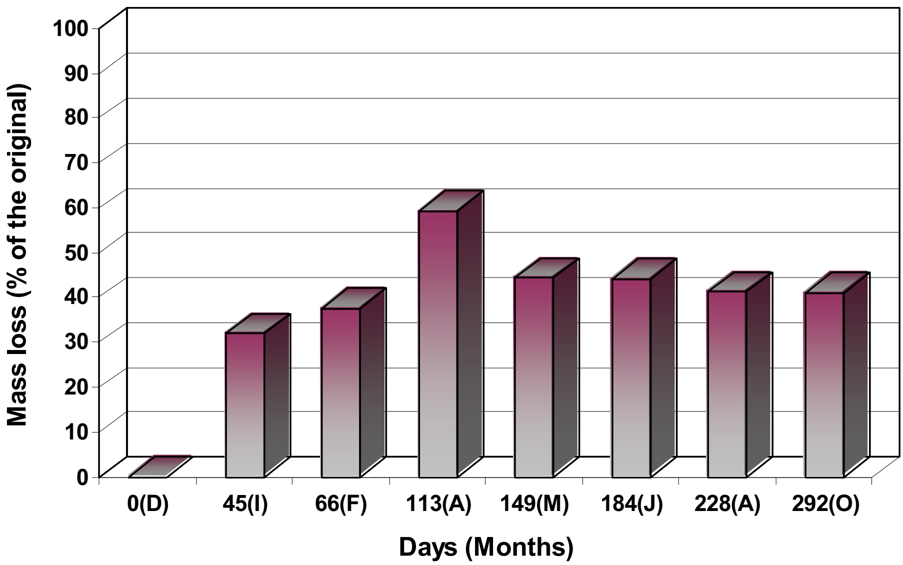


Figure 2. Dry mass loss of leguminous material (ash-free) from the mesh bags during the sampling period. Date of burial (day 0 at the diagram): 14/12/1994

## 4 CONCLUSIONS

In the studied site, where the fieldwork started 18 months after the fire event, the decomposition of pure cellulose is accomplished in 228 days. This time period is much shorter than the relevant one (more than 360 days) in a severely burned Aleppo pine forest of Mt. Penteli, Attica, where the field work started 3 months after the fire event (Radea and Arianoutsou 2000). This difference could be attributed to the individual characteristics and the post-fire age of the recovering sites under consideration. There is abundant evidence that post-fire age influences greatly the qualitative and quantitative structure of soil communities of both invertebrates and microbes and their decomposing activity (Ahlgren and Ahlgren 1965, Prodon et al., 1987, Broza and Izhaki 1997, Hernandez et al. 1997, Radea and Arianoutsou 2000).

The cellulose decomposition rate in the studied site is also faster comparing with that in an unburned Aleppo pine forest of Mt. Parnitha, Attica, where this process took place in more than 400 days (Arianoutsou and Radea unpubl. data). Probably this fact could be partly explained by the increasing leaching in the burned site where no plant canopy exist and partly by the high abundance of legumes in the burned site. It is well known that the presence of legumes accelerates the rate of decomposition of organic matter because these nitrogen fixers affect significantly the quantity and the quality of decomposer microorganisms owing to the higher carbon and nitrogen availability in the soil (Halvorson et al. 1991, Halvorson and Smith 1995, Spehn et al. 2000)

The time required for the completion of decomposition of legume material is found to be much longer than that found for pure cellulose. This fact was expected because of the structural complexity of the plant tissues, which retain their chemical components against leaching and decomposition. However, the decomposition rates of legume herbs seem to be higher in the studied site than that in experimental agroecosystems of Greece (Kalburtji and Mamolos 2000), at least at the initial decomposition stages.

Smith et al. (1998) found that leaf litter derived from legume trees had decomposition rates significantly higher than that from other tree species in plantation and primary forests in lowland Amazonia. Rather slow decomposition rates of litter from legume trees were estimated by Zhi-an Li et al. (2001) in subtropical plantations of China. The above authors clearly demonstrate that the relatively low decomposition rates of legume litter and its higher nitrogen content are important factors in the build up of nitrogen stocks in the soil which, in turn, has a comparatively higher nitrogen mineralization potential.

In general, the levels of soil nitrogen in forms available for plant uptake have been reported to be higher in burned than in unburned Mediterranean pine forests, shortly after the fire event (Kutiel and Naveh 1987b, Kutiel and Shahiv 1989, Hernandez et al., 1997). However, soil nitrogen level declines after the first post-fire months (Kutiel et al. 1990, Papavassiliou 2001) and reaches almost the values of the unburned pine forest 18 months after the fire event (Kutiel et al. 1990).

Under the circumstances of the post-fire recovery process where regenerating plants have not yet shed leaves as massively as the annual herbaceous legumes, the litter of legumes would serve as a direct input of nitrogen in the soil nutrient pools through its relatively slow decomposition. Consequently, it is reasonable to state that the key-role of legumes in the post-fire communities is not delineated only in their nitrogen fixing ability but also in their decomposition attributes.

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