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Effects of plant post-fire persistence traits on soil microbial biomass and activity in Mediterranean shrublands

R. López-Poma (*), S. Bautista

Departamento de Ecología, Universidad de Alicante, Apdo. 99, E-03080, Alicante, Spain
*Corresponding author: rosario.lp@ua.es

Keywords

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Abstract

The strong relationships between plant and soil microbial communities suggest that post-fire vegetation may be a critical driver of the post-fire recovery of the structure and functioning of the soil microbial community. In this study, we conducted an experimental burning and evaluated the effect of the post-fire persistence traits of the vegetation (resprouter and seeder) on the medium-term (3 years after fire) post-fire response of the soil microbial activity in Mediterranean shrublands. The experiment was carried out in a Mediterranean shrubland (Eastern Spain), where four main types of microsites were selected: Bare-soil inter-patch (BS); Resprouter patch (R), Seeder patch (S), and Mixed patch (R+S). For each microsite, we analyzed soil basal respiration, water-soluble carbon, microbial biomass carbon, total organic carbon, and dehydrogenase activity at 0-5 cm soil depth. We also assessed plant cover dynamics. Our results suggest that, in general, fire impacts on soil microbial activity are not long-lasting, with most assessed soil variables being similar between burned and unburned areas three years after the fire. However, while the unburned microsites showed a trend in microbial biomass and activity from lower values in bare soils to higher values in R+S patches, these differences disappeared in the burned area, due to both a slight increase in microbial activity and biomass in bare soils, and the opposite response for soils under R+S patches. Our results highlight the role of the plant persistence trait in the microbial post-fire response of Mediterranean soils.

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1 Introduction

Fire alters the soil microbial community structure at the short-term, mainly through heat-induced microbial mortality (DeBano et al., 1998). Over the long-term, fire may modify soil communities by altering plant community composition, as plants induce changes in the soil environment (Hart et al., 2005). Previous works in Mediterranean areas have shown that fire caused a significant shift in the microbial community structure, biomass C, respiration and soil enzyme activities, but results showed both increasing and decreasing tendencies, depending on the plant community and the time after fire considered (Fioretto et al., 2005; Goberna et al., 2012). Post-fire plant recovery results from resprouting from above or underground structures and germination from seeds stored in soil and canopy banks, which are the main persistence traits of the vegetation after fire (Keeley, 1986; Pausas et al., 2004). We hypothesize that these traits modulate the response of the soil microbial communities after fire. The main objective of this study was to evaluate the effect of the plant post-fire persistence traits on the medium-term (3 years after fire) response of the soil microbial activity to fire in Mediterranean shrublands.

2 Methods

The study area is located in Caroche range (39°07'N 0°57'W), at Teresa de Cofrentes, Valencia, Eastern Spain. The experimental site was established on a Mediterranean shrubland area, where four main types of microsites were selected as experimental treatments: Bare-soil inter-patch (BS); Resprouter patch (R), dominated mainly by *Erica mutiflora*; Seeder patch (S), dominated by *Rosmarinus*

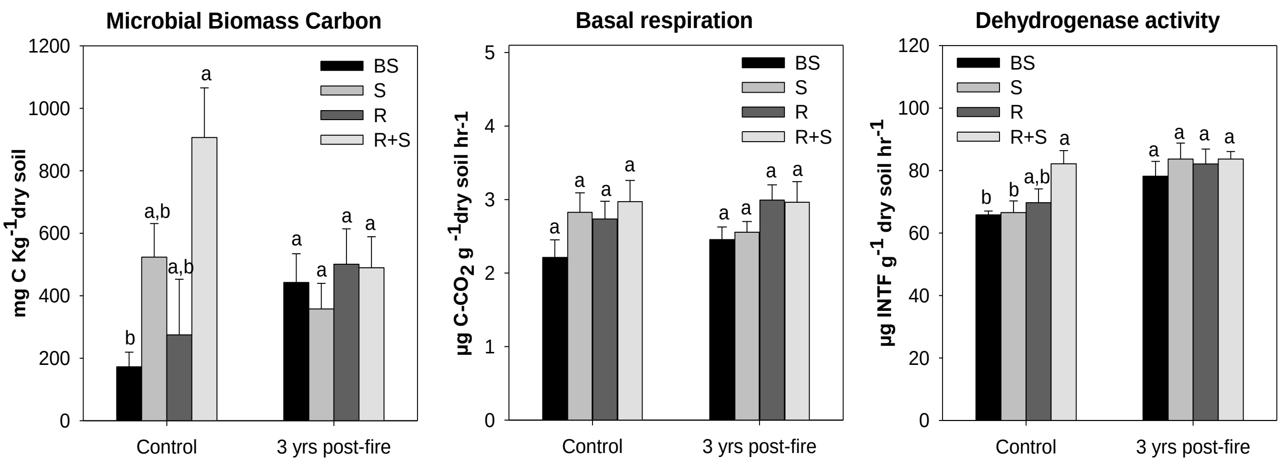

Figure 1. Microbial biomass carbon (left), Basal respiration (middle), and Dehydrogenase activity (right), for bare soil (BS), and soil under Seeder (S), Resprouter (R), and Seeder and Resprouter (R+S) patches, in unburned control (UB) and burned (3 years after fire) plots.

officinalis L.; and Mixed patch (R+S), composed by a mixture of resprouter and seeder species. In May 2009, we conducted an experimental burning on the experimental site; a contiguous plot was left unburned as control area. Three years after the fire, twelve soil samples were taken for each treatment and both conditions: burned and unburned. After removing the litter layer, the soils were sampled at 0-5 cm depth. The samples were sieved (<2mm) and stored at 4 ^{o}C.

Basal respiration (BR) was determined on soils moistened up to 50% of their water holding capacity, and incubated in hermetically sealed flasks in the dark at 24 ^{o}C, 48 hours. *Water-soluble carbon* (WSC) was quantified colorimetrically after oxidation with $K_2Cr_2O_7$. *Microbial biomass carbon (MBC)* was determined using the fumigation-extraction procedure and then quantified colorimetrically as described above for water-soluble carbon. *Dehydrogenase activity* (DHA) was determined according to Garcia et al. (1997). Soils at 60% of its water holding capacity were treated with 0.4% INT (2-p-iodophenyl-3-p-nitrophenyl-5-phenyltetrazolium chloride) for 24 h at 24 ^{o}C in darkness; the iodo-nitrotetrazolium formazan (INTF) formed was then extracted with methanol by shaking and filtering, and measured spectrophotometrically at 490 nm. Total organic carbon (OC) was determined by the Mebius method.

One way ANOVA was used to compare soil variables (BR, WSC, MBC, DHA, and OC), and plant cover between microsite types (BS, R, S, R+S), for both burned and unburned onditions. Two-way ANOVA was used to assess the effects of Fire and Microsite Effects on soil microbial and biochemical properties.

3 Results

Three years after the fire, we found only marginal differences in soil basal respiration, dehydrogenase activity and microbial biomass carbon between burned and unburned microsites (Figure 1; Table 1). Dehydrogenase activity showed a slight increase in the burned microsites, probably still reflecting short-term increase in general microbial activity after the fire (Goberna et al., 2012). Though there was not a global fire effect on microbial biomass, the interaction between fire and microsite effects (Table 1) highlights the role of plant persistence traits as modulators of soil microbial response to fire. Thus, while bare soils and soils under Resprouter (R) patches hardly changed their microbial biomass, soils under Seeder (S) patches, and particularly under R+S patches showed lower microbial biomass in burned (3-years post fire) than in unburned patches (Figure 1).

In general, the unburned microsites showed a trend in microbial biomass and activity from bare soil, which showed the lowest values, to R+S patches, with the highest values, probably due to the contribution of a variety of root exudates and litter. This trend was not found in the burned microsites, which did not show any difference between treatments (Figure 1). A slight increase in microbial activity and biomass in bare soils, and the opposite response for soils under R+S patches explain this post-fire homogenization in microbial activity between

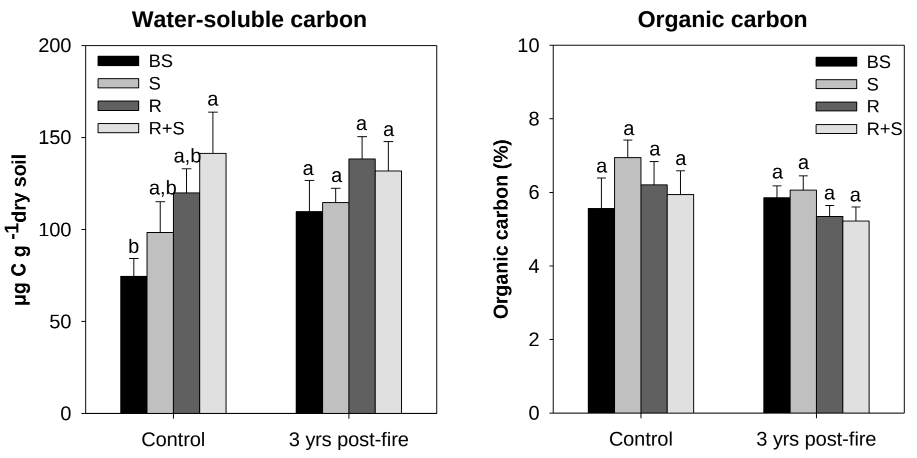

Figure 2. Water-soluble carbon (left) and total Organic carbon (right) for bare soil (BS), and soil under Seeder (S), Resprouter (R), and Seeder and Resprouter (R+S) patches, in unburned control (UB) and burned (3 years after fire) plots.

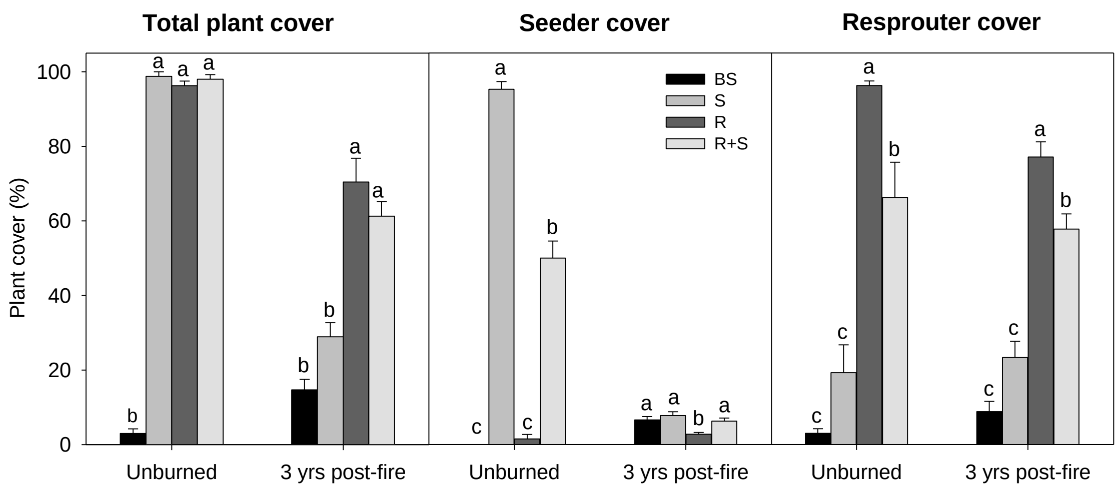

Figure 3. Total plant cover, and plant cover of seeder and resprouter species for bare soil (BS), and Seeder (S), Resprouter (R), and Seeder and Resprouter mixed (R+S) patches, in unburned control (UB) and burned (3 years after fire) plots.

treatments. Bare soils probably benefited from post-fire redistribution of labile carbon and nutrients through ashes and runoff, while R+S patches were adversely affected by a post-fire decrease in plant functional diversity, as three years after the fire R+S plant cover consisted mostly of resprouting species (Figure 3). Microbial biomass and activity results were consistent with the variation in water-soluble carbon (WSC), which also showed an increasing, though no significant, trend -from bare soils to R+S patches- that was later homogenized after the fire (Figure 2). However, total organic carbon did not show any fire or microsite effect.

Our results suggest that global fire impacts on soil microbial activity, as described in previous works (Goberna et al., 2012; Hernández et al., 1997), are not long-lasting, with a number of indicators of this general microbial activity being similar between burned and unburned areas three years after the fire. However, some differences still remain, which vary depending on the dominant plant persistence trait of the various types of microsites that can be found in Mediterranean shrublands.

Table 1. Statistic results from General Linear Model Analysis of Fire and Microsite Effects on soil microbial and biochemical properties. (*) p ≤ 0.05.

	Fire (F)		Microsite (M)		Interaction (F x M)	
	F	p	F	p	F	p
Basal respiration	0.056	0.813	1.990	0.126	0.452	0.717
Water-soluble carbon	1.480	0.229	2.776	0.050*	0.566	0.640
Dehydrogenase activity	7.393	0.009*	1.323	0.276	0.685	0.565
Microbial biomass carbon	0.059	0.809	3.054	0.034*	2.884	0.044*
Total organic carbon	2.252	0.139	1.344	0.269	0.618	0.606

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