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Short-term effects of wildfire on microbial biomass and abundance in black pine plantation soils in Turkey

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ABSTRACT

Measurement of soil microbial biomass and abundance offers a means of assessing the response of all microbial populations to changes in the soil environment after a fire. We examined the effects of wildfire on microbial biomass C and N, and abundance of bacteria and fungi 2 months after a fire in a pine plantation. Soil organic carbon (C_{org}), total nitrogen (N_{tot}), and electrical conductivity (EC) increased following the fire. In terms of microbial abundance, the overall results showed that burned forest soils had the most bacteria and fungi. Microbial biomass C and N from soil in the burned forest were not significantly different from their unburned forest counterparts. However, microbial indices indicated that fire affects soil microbial community structure by modifying the environmental conditions. The results also suggested that low-intensity fire promotes microorganism functional activity and improves the chemical characteristics of soils under humid climatic conditions.

1. Introduction

Wildfire disturbance has received a great deal of attention because of its critical role in forest ecosystems of the Mediterranean Basin. In modern forestry, wildfires are considered undesirable, because fire destroys vegetation cover and reduce soil fertility due to erosion and nutrient losses (Fernández et al., 2007). Indeed, soil degradation caused by wildfires produces important changes in the physical, chemical, and biological properties of soil (Acea and Carballas, 1996). This has led to intensive fire suppression, although wildfires still affect approximately 600 000 ha of bushy and woody environments in the Mediterranean Basin each year (Palese et al., 2004). In Turkey, 2829 forest fires burned a total area of 9625 ha in 2007.

Soil productivity and nutrient cycling are influenced by the amount and activity of microorganisms, which are key components in maintaining soil fertility (Jenkinson and Ladd, 1981). Soil microbial biomass acts as an important ecological indicator and is responsible for the decomposition and mineralization of plant and animal residues in the soil (Marinari et al., 2006). Microbial biomass might be a main source of nutrients for plants and might contribute to nutrient conservation (Dick, 1992).

Soil microorganisms are integral parts of forest ecosystems and suffer from various fire effects. The immediate effect of fire on the microbial community is complex and can range from reduction to elimination or no effect (Vazquez et al., 1993; Dumontet et al., 1996). The combustion of organic matter releases significant quantities of available nutrients and can be an important source for plant growth. Mineral ash can also influence the soil pH, as well as microbial activity related to decomposition and nutrient turnover (Kauffman et al., 1992).

Forest fires are common events in Turkey. However, limited research has examined wildfire impacts on soil microorganisms in Turkish forests (Azaz and Pekel, 2002; Ekinci and Kavdir, 2005). An understanding of wildfire impacts is needed to effectively manage forest ecosystems, including post-fire management decisions regarding seeding options, erosion control, and other interventions.

Here we investigated the effects of wildfire on soil microbial biomass carbon (Cmic) and nitrogen (Nmic), and the abundance of fungi and bacteria in a black pine (*Pinus nigra* Arnold) plantation located in north-western Turkey (Bartın) 2 months after a fire. We examined the relationship between microbial community structure and the physico-chemical properties of soil that has been exposed to fire.

2. Materials and methods

2.1. Study site

The study site was located near the city of Bartın in north-western Turkey (200 m above sea level). The plantation in the research area has been stable for more than 20 years and is

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dominated by black pine. The climate of this region is humid mesothermal, characterized by warm summers. Based on climatological data from the past 30 years, the annual mean temperature in this province is 12.6 °C. The mean temperatures of the hottest months, July and August, are 22.4 and 21.9 °C, respectively. Annual mean precipitation in the region is 1087 mm and annual relative humidity is 80%. The principal geological formation of the research area is calcareous rock. The soils at the study site are of the Alfisol order. These soils are deep, slightly alkaline, well-drained and have very strong soil horizons.

A canopy fire occurred in this area on 21 August 2006, affecting 6 ha of the black pine plantation. It lasted for less than 1 day and killed most of the standing trees. Measurements of fire intensity and soil temperature were not available because of the accidental nature of the fire. However, the fire appears to have been of low intensity because there was not much fuel on the soil surface and the ashes were not white.

2.2. Soil sampling

This study was conducted with a completely randomized design. Soil samples were taken from six different plots (10 m × 10 m) in each site (burned and unburned) on 18 October 2006, at sampling points with similar physiography, topography, and parent rock. Each plot was divided into two equal subplots. Soil samples consisted of a mixture of three randomly collected soil subsamples taken from the upper, middle and lower part of each subplot. The litter layer was removed before soil samples were taken at a depth of 5 cm. All visible roots and coarse fragments (>2 mm) were removed. Soil samples were passed through 2-mm sieves and stored at 4 °C until microbial analysis. At each site, 12 extra samples of surface mineral soil (0–5 cm) were collected to determine the physical and chemical properties of the soil.

2.3. Physical and chemical properties of soils

Soil physical and chemical properties were determined by the appropriate method: soil particle size distribution by the hydrometer method, pH of a 1:2.5 soil/water suspension with a pH meter, electrical conductivity (EC) in a 1:5 soil/water suspension with an EC meter, soil organic matter by the Walkley-Black wet oxidation method, total nitrogen by the Kjeldahl method, and $CaCO_3$ content by the Scheibler calcimeter method (Rowell, 1994).

2.4. Microbial biomass C (C_{mic})

Soil microbial biomass C (C_{mic}) was estimated by extracting 30-g oven-dry equivalents of field-moist mineral soil samples in 0.5 M K_2SO_4 (1:4 w/v) by the chloroform-fumigation-extraction method described by Brookes et al. (1985) and Vance et al. (1987). C_{mic} was calculated from the difference in extractable organic C between fumigated and unfumigated soil samples as follows: biomass C = 2.64 E_C, where E_C refers to the difference in extractable organic C between the fumigated and unfumigated treatments; 2.64 is the proportionality factor for biomass C released by fumigation extraction (Vance et al., 1987).

2.5. Microbial biomass N (N_{mic})

The Kjeldahl digestion–distillation–titration method was used to determine the total N in K_2SO_4 (Anderson and Ingram, 1993). N_{mic} was calculated (Brookes et al., 1985) using the equation biomass N = F_N/0.54, where F_N = (total N from fumigated soil) − (total N from unfumigated soil).

2.6. Microbial count

To estimate total bacteria and fungi, a method similar to that of Tateishi et al. (1989) was used to dilute the soil to a 10^{-5} dilution in sterile water. For bacteria, sterile nutrient agar plates were aseptically inoculated with 1 ml of dilutions (10^{-5}) of the samples and incubated at 30 °C for 24 h. Fungi were enumerated using potato dextrose agar (PDA) plates that had been supplemented with streptomycin (100 g ml^{-1}) to inhibit the growth of bacteria. Sterile PDA plates were aseptically inoculated with 1 ml of dilutions (10^{-4}) of the samples and incubated at 30 °C for 72 h. After the incubation period, plates with distinct colonies were counted. The mean of three subsamples was obtained. The numbers of bacteria and fungi were calculated as colony forming units CFU g^{-1} dry soil.

2.7. Statistical analyses

Data for microbial abundance, microbial biomass, and physical and chemical characteristics of soil were subjected to independent sample *t*-tests to determine significant differences between the burned and unburned sites. A correlation analysis was used to examine the relationships among microbial parameters and EC, organic carbon (C_{org}), and total N (N_{tot}).

3. Results

3.1. Physical and chemical characteristics of the soils

The soil texture of the burned and unburned areas was classified as clay (Table 1). Two months after the fire, the pH of the burned soil was 0.13 units higher than that of the unburned controls, although the difference was not significant (Table 1). Compared to the unburned site, EC was markedly higher in the burned soil, reaching as high as 0.30 dS m^{-1} after the fire (Table 1). Organic carbon varied from 32.80 to 66.60 mg g^{-1} in the burned soils and from 13.80 to 55.70 mg g^{-1} in the unburned soils (Table 1). The level of nitrogen varied from 2.93 to 4.50 mg g^{-1} in the burned soils and from 1.54 to 4.28 mg g^{-1} in the unburned soils (Table 1).

3.2. Microbial counts

The mean fungal count was 49.16 × 10^4 CFU g^{-1} in the unburned soils and 77.16 × 10^4 CFU g^{-1} in the burned soils. The mean bacterial count was 58.8 × 10^5 CFU g^{-1} in the unburned soils and 333.83 × 10^5 CFU g^{-1} in the burned soils. There was a significant difference in the fungal and bacterial counts between the burned and unburned sites (Fig. 1a and b). The bacterial count was significantly, positively related to EC, C_{org}, and N_{tot} (Table 2).

Table 1
Physical and chemical characteristics of black pine soils (0–5 cm depth).

Soil characteristic	Burned sites	Unburned sites
Sand (%)	21.48 (±3.66)[aA]	19.61 (±1.91)[a]
Silt (%)	26.31 (±3.27)[a]	19.33 (±3.22)[b]
Clay (%)	52.21 (±4.96)[a]	61.06 (±3.21)[b]
Soil texture	Clay	Clay
Bulk density (g cm^{-3})	1.14 (±0.07)[a]	1.18 (±0.06)[a]
pH in water	7.74 (±0.04)[a]	7.61 (±0.24)[a]
Electrical conductivity (dS m^{-1})	0.30 (±0.03)[a]	0.19 (±0.02)[b]
$CaCO_3$ (%)	20.11 (±6.39)[a]	13.91 (±12.77)[a]
Organic carbon (mg g^{-1})	55.88 (±13.66)[a]	30.25 (±15.77)[b]
Total nitrogen (mg g^{-1})	3.82 (±0.68)[a]	2.70 (±1.03)[b]

Different letters indicate a significant difference ($P < 0.05$) between sites (independent sample *t*-test).
[A] Values represent the means of 12 samples (± S.D.).