Rhizosphere influence on soil microbial biomass and enzyme activity in banj oak, chir pine and banj oak regeneration forests in the central Himalaya

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Introduction

The rhizosphere is a dynamic soil ecosystem, with a large part of the activity affecting the transfer of energy and nutrients (Kuzyakov, 2002; Hinsinger et al., 2009). Distribution of soil microbial community depends on vegetation type, soil properties and climatic conditions (Chen et al., 2017).

The root efflux and nutrient uptake capacity varies with tree species and depends mainly on the root morphology and their activity (Lovett et al., 2004).

The central Himalayan exhibit wide range of flora and fauna and mainly dominated by two evergreen tree species namely banj oak (*Quercus leucotrichophora*) and chir pine (*pinus roxburghii*). Banj oak is found at an elevation range of 1500 to 2300 m and chir pine is reported in a range of 900 to 1800 m asl.

Objective

(i) To explore the soil carbon and nutrients, microbial biomass and enzyme activity in rhizosphere and bulk soil of different forest ecosystems.

(ii) To evaluate the rhizosphere soil microbial index (RSMI) as an indicator of soil health.

Materials and Methods

Study site description

The study site was located in Kumaun hills region at Lamgara block of Almora district, Uttarakhand, India, at latitudes of 29º 31´ 67´´ N to 29º 32´ 78´´ N and at longitudes of 79º 44´ 72´´ E to 79º 45´ 50´´ E. This study focuses on the three selected forests, banj oak forest (Kapkot), chir pine forest (Dabri), banj oak regeneration forest (That).

Soil sampling

The soil samples were collected in triplicate from rhizosphere soil and bulk soil at three depths (0-10 cm, 10-20 cm, 20-30 cm), with the help of corer (diameter 5.6 cm). The soil tightly adhering to the roots was considered as rhizosphere soil and the bulk soil samples were collected from the area without vegetation (Garcia et al., 2005).

Methodology

Soil microbial biomass carbon (Cmic), nitrogen (Nmic), phosphorus (Pmic) were estimated by chloroform fumigation-extraction (FE) method (Brookes et al., 1985). The soil dehydrogenase activity was determined by following Klein et al., (1971).

$$Cmic = \frac{EC(f) - EC(nf)}{KEC}$$

Where *EC (f)* = extracted carbon from fumigated soil sample, *EC (nf)* = extracted carbon from non-fumigated soil, *KEC* = 0.45 (Vance et al., 1987).

Results:

Soil physicochemical properties

Soil organic carbon (SOC) was higher in rhizosphere compared to bulk soil and ranged from 1.08 % (bulk soil of chir pine forest) to 1.7 % (rhizosphere of the banj oak forest). Soil total nitrogen (TN) ranged from 0.12 % (in the bulk soil of banj oak regeneration forest) to 0.21 % (in the rhizosphere of the banj oak forest), while available phosphorus (Pav) ranged from 0.02 % (bulk soil of chir pine) to 0.03 % (rhizosphere of banj oak forest) and decreased with soil depths.

Soil Biological Properties

The soil Cmic, Nmic, Pmic and DHA were higher in rhizosphere of banj oak forest followed by banj oak regeneration and minimum in chir pine forest (Fig. 1).

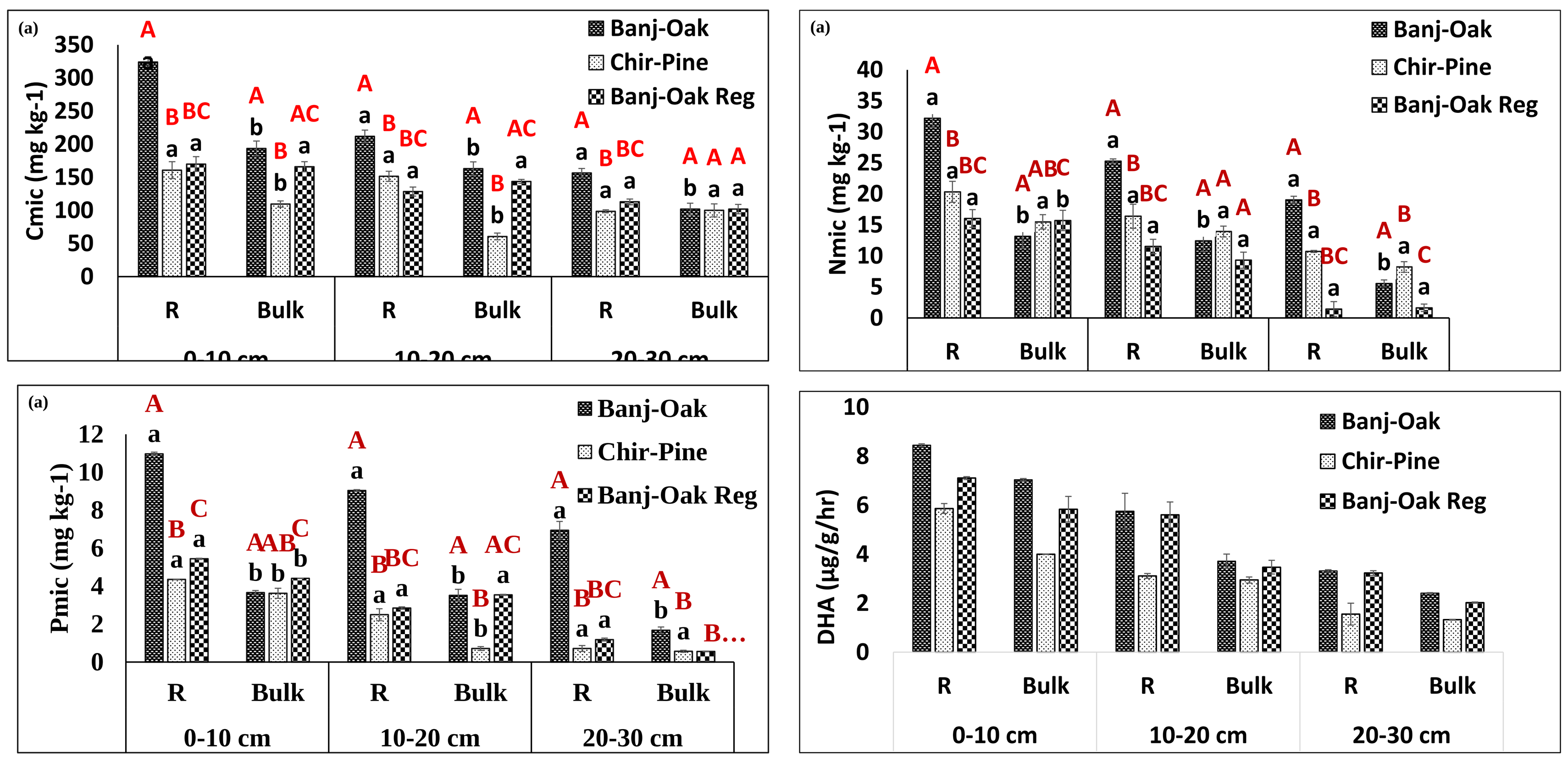


Fig. 1 Soil biological properties. (a) Microbial biomass carbon (Cmic), nitrogen (Nmic), Phosphorus (Pmic) and dehydrogenase enzyme activity(DHA). By soil depth, values of same vegetation type the various lower-case letters indicate significant difference. By vegetation types, values of same soil depth follow the various upper-case letters significantly different (p<0.05). R = rhizosphere soil, bulk = bulk soil.

Rhizosphere soil microbial index (RSMI)

$$RSMI = 0.63\left[\frac{1}{1+\left(\frac{x_1}{3.5}\right)^{-2.5}}\right] + 0.20\left[\frac{1}{1+\left(\frac{x_2}{1.0}\right)^{-2.5}}\right] + 0.16\left[\frac{1}{1+\left(\frac{x_3}{1.2}\right)^{-2.5}}\right]$$

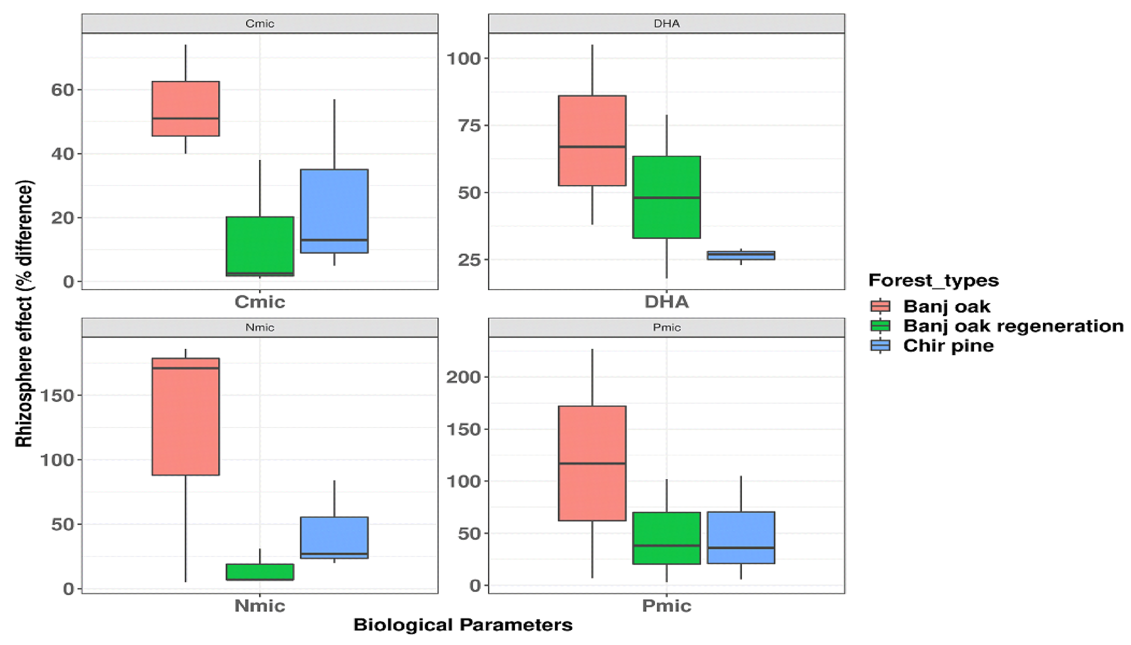
Where x_1, x_2 and x_3 represent Pmic, Pmic/Pav and Cmic/SOC, respectively.

Discussion

Higher soil nutrients and microbial biomass in the rhizosphere soil indicates high efflux of carbon containing organic compound by the roots of the tree species. Among the forests, rhizosphere soil of banj oak forest contain higher nutrient and soil microbial biomass indicates that the high soil moisture content and nutrient rich soil make the roots healthy results in high root exudation.

The rhizosphere soil of banj oak forest has 1.6 times higher dehydrogenase enzyme activity than the bulk soil, while it was 2 times higher in banj oak regeneration and 1.1 times in chir pine forest. Higher soil microbial biomass in the rhizosphere indicated that rhizosphere soil has higher microbial counts than the bulk soil.

Magnitude of rhizosphere effect (% difference)



Rhizosphere soil microbial index (RSMI) value was maximum for banj oak forest (0.68) followed by chir pine (0.45) and minimum for banj oak regeneration forest (0.44). The banj oak tree species may be recommended for maintenance of soil health and belowground processes.

Conclusion

We found that rhizosphere of tree species significantly influenced the soil microbial biomass, enzyme activity and varied with tree species. Forest with high nutrients level (banj oak) exert more rhizosphere influence than the forest with nutrients poor soil (chir pine).

Banj oak forest has high nutrient concentration, support microbial community and under canopy vegetation which may consequently help in improving soil physical, chemical and biological properties.

Regeneration of banj oak in chir pine improves rhizosphere soil quality through increasing soil moisture content, SOM, nutrients, soil microbial biomass and dehydrogenase enzyme activity compared to monoculture stand of chir pine forest.

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