

## Original Research Article

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# Impact of Canopy and Seasonal Dynamics on Different Forest Soil Microbial Community Composition in Mid Hills of Himachal Pradesh

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## A B S T R A C T

A substantial parameter that links plants to the soil is microbial biomass. Measurement of the biologically-active fractions of the soil organic matter, is a good way to quantify the quality of the soil. In the study, the impact of canopy and seasonal dynamics on different forest soil microbial community composition in Mid Hills of Himachal Pradesh were investigated in the forest floor under a stand of five forest ecosystems. Soil samples were collected from the organic layer and topsoil. Microbial biomass was determined by using soil fumigation extraction method and enumeration of microbial population was done by plate count technique through serial dilution using a variety of media. The study revealed that seasonal changes have a significant effect on the quantities of microbial biomass and count found in the forest floor. According to our study, the greatest amount of microbial biomass and count in the forest floor occurred during summer season. The total microbial count (Bacteria 206.97cfu g<sup>-1</sup>, Fungi 2.22cfu g<sup>-1</sup> and Actinomycetes 8.78cfu g<sup>-1</sup>) was found highest in Ban Oak Forest and about 1521.37 µg C g<sup>-1</sup> registered highest soil microbial biomass under Ban Oak Forest. The microbial properties followed the trend of Ban Oak Forest > Mixed Forest > Chir Pine Forest > Agriculture Field > Bare Area. The results indicates that litter quality and seasonal dynamics associated with different environmental factors like pH, moisture and temperature are crucial in determining the relative abundance of soil microbial community found in different forest ecosystem.

### Keywords

Forest ecosystem,  
 Meteorological factors,  
 Microbial count, Soil  
 microbial biomass and  
 Soil nutrient pool

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## Introduction

Quality and quantity of litter and various environmental factors in forest soils determine the microbial community composition. Litter decomposition rates depend on microbial community structure and activity (Esperschutz *et al.*, 2013). Many studies has been reported for the impact of plant species and vegetation type (Meng *et al.*, 2012; Banning *et al.*, 2011) on soil microbial composition. Microbial

parameters are proposed as rapid and sensitive indicators for detecting changes in soils. Biotic interaction and substrate availability in natural forests influence microbial decomposer communities (Chapman *et al.*, 2013).

The changes in microbial biomass or abundance of selected functional groups of microorganisms (e.g. mycorrhizal fungi) can be detected precisely and rapidly when

compared to changes in soil organic matter content or other soil physical and chemical properties (Pankhurst *et al.*, 1997). Soil metabolic activities depend on microbial species composition, which in turn influenced by litter availability, soil type and other environmental factors (Samuel, 2010). The environmental factors that regulate microbial community composition may assist to understand soil biogeochemical processes (Keith-Roach *et al.*, 2002). The seasonal changes affect the soil moisture, soil temperature, root activity and amount of organic matter give rise to fluctuations in the soil. Also, these fluctuations vary according to factors such as soil type, amount and type of vegetation, land use and management (Kramer and Green 2000; Chen *et al.*, 2003).

Soil microorganisms are potentially useful indicators of soil health and quality. Soil microorganisms contribute to the maintenance of soil health and quality by controlling processes, such as decomposition of animal-plant residues, biogeochemical cycles, formation of soil structure and its maintenance, and the fate of agrochemicals and pollutants applied to soil. Today, international programs for monitoring soil health and quality involve the measurement of several biochemical properties such as microbial biomass and microbial diversity (Nielsen and Winding, 2002; Alvarez *et al.*, 2009).

In this study, we aim to evaluate the impact of canopy cover (oak and pine litter) and season dynamics on relative abundance of soil microbial community, soil organic and microbial biomass carbon in different forest ecosystem.

## Materials and Methods

The study was conducted in different forest ecosystems at University campus of Nauni,

Solan, Himachal Pradesh. The investigation was carried out in Dr. Yashwant Singh Parmar University of Horticulture and Forestry Nauni, Solan (HP) during winter and summer season of 2015-16. The area is situated between 30.52° N and 77.10° E with elevation ranges from 1232 to 1264m. The research area was divided into five different sites as Chir Pine forest (F1), Mixed forest (F2), Ban Oak forest (F3), Agricultural field (F4) and Bare area (F5) as shown in Figure 1.

## Ecology and biological properties were determined in the laboratory by using following methods:

### Litter layer characteristics

A general forest floor survey was conducted at each forest using destructive sampling and percent coverage of litter, moss and plant species were recorded as shown in Table 1. A destructive sampling method was used over the two seasons (winter and summer) to collect seasonal data at 1400-1600 hrs on litter and moss moisture content through various drying and wetting periods along altitudinal variations as described by Wotton *et al.*, (2005).

### Destructive sampling technique

Destructive sampling method was used to measure mean surface loading by collecting the samples at each sampling location using a 900 cm<sup>2</sup> grid. Averages amongst the four replicates in different forests viz., Chir pine forest (F<sub>1</sub>), Mixed forest (F<sub>2</sub>) and Ban oak forest (F<sub>3</sub>) for each substrate layer were used to determine a value for total surface loading at each site. Surface thickness of litter layer was measured with the help of meter rod. However, the forest ecosystem having different forest vegetation have dead and decaying material lying on the ground as per the forest area and no such material was found

in agriculture field and bare area (control conditions). Therefore, for completion of minimum requirement of design (RBD factorial) and for statistical analysis of litter layer characteristics, the number of replications have been increased to four by considering different forest types viz., chir pine forest ( $F_1$ ), mixed forest ( $F_2$ ) and ban oak forest ( $F_3$ ), during winter and summer seasons of 2015-2016.

### Total microbial count

The enumeration of microbial population was done by plate count technique through serial dilution using a variety of media (Wollum, 1982).

### Microbial biomass

The biomass was obtained by using soil fumigation- extraction method given by Vance *et al.*, (1987).

### Results and Discussion

The important litter layer characteristics Viz. surface loading and surface thickness were taken into account to exhibit significant microclimatic variation under selected forest ecosystem results obtained are presented as under:

### Surface loading

The data represents the interaction of mean surface loading in three different forest types during winter and summer season 2015-2016 as shown in Table 2. Significant difference was found between three forests in mean surface loading during winter and summer seasons. The maximum surface loading of ( $1.75 \text{ kg m}^{-2}$ ) was observed in Chir pine forest ( $F_1$ ) and minimum of ( $0.24 \text{ kg m}^{-2}$ ) in mixed forest ( $F_2$ ). The maximum surface loading was found in summer season ( $0.93 \text{ kg m}^{-2}$ ) than

winter season ( $0.61 \text{ kg m}^{-2}$ ). The interaction of forest type X season on surface loading of mid hills of HP was found to be significant. The maximum surface loading was found in chir pine forest ( $F_1$ ) during summer season ( $2.16 \text{ kg m}^{-2}$ ) and minimum in mixed forest ( $F_2$ ) during summer season ( $0.16 \text{ kg m}^{-2}$ ). The results were probably due to woody material was found on the surface of forest floor of chir pine forest consisted of volatile material with minimum decomposition rate, year to year build up as compared to ban oak and mixed forest.

### Surface thickness

Table 2 depicts the microclimatic seasonal variations and interactions of surface thickness in all forest types during winter and summer season in 2015-2016. Significant differences were obtained in all three forests during winter and summer seasons. The maximum surface thickness of ( $2.91 \text{ cm}$ ) was found in chir pine forest ( $F_1$ ) and minimum in ban oak forest ( $F_3$ ) ( $1.28 \text{ cm}$ ). Surface thickness of summer season ( $2.02 \text{ cm}$ ) was significantly higher than winter season ( $1.58 \text{ cm}$ ). The interaction of forest type X season on surface thickness of mid hills of HP was found to be significant. The maximum surface thickness ( $3.52 \text{ cm}$ ) was found in chir pine forest ( $F_1$ ) during summer season and minimum ( $0.82 \text{ cm}$ ) in mixed forest ( $F_2$ ) during summer season which was statistically at par with ban oak forest ( $F_3$ ) ( $0.83 \text{ cm}$ ) during winter season. The results were probably due to structure and composition of the decomposed material, the underlying organic layer and soil. The results are in consonance with Sohng *et al.*, (2014) and Nelson (2001).

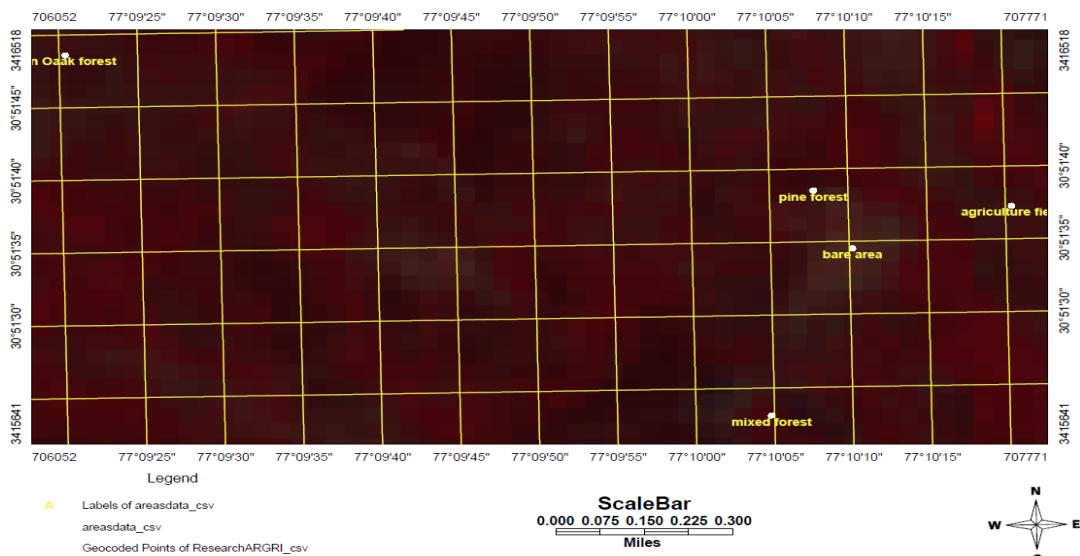
The important biological properties Viz. microbial count and microbial biomass were analysed for studying the microclimatic variations among different forest ecosystem. The results obtained are presented as under:

## Microbial count

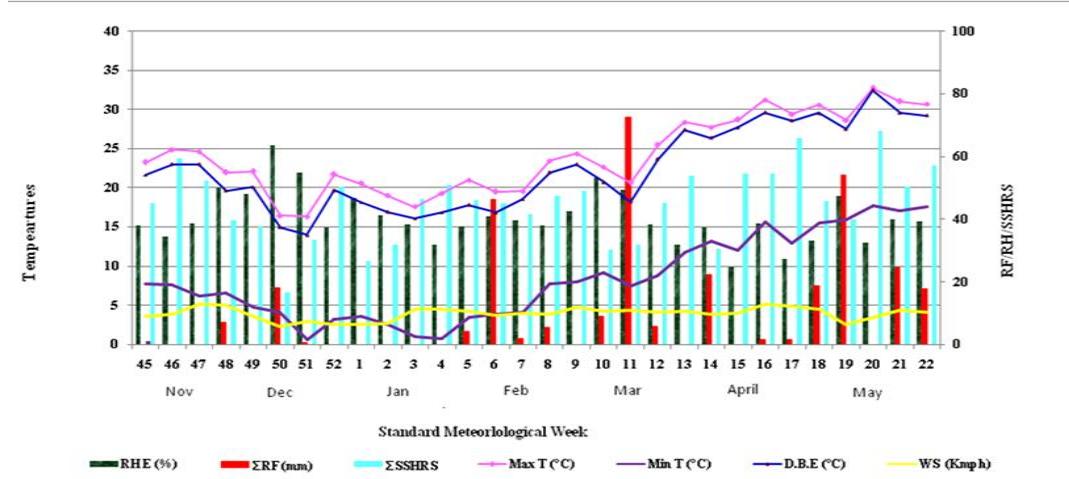
The perusal of the data revealed in Table 3 a significant difference in the microbial count among different forest ecosystem and seasons. The highest bacterial count was observed in ban oak forest ( $F_3$ ) ( $206.97 \text{ cfu g}^{-1}$ ) followed by mixed forest ( $F_2$ ) ( $203.68 \text{ cfu g}^{-1}$ ) and chir pine forest ( $F_1$ ) ( $161.77 \text{ cfu g}^{-1}$ ). The lowest bacterial count was observed under bare area ( $F_5$ ) of  $40.50 \text{ cfu g}^{-1}$ . The maximum bacterial

count of  $182.93 \text{ cfu g}^{-1}$  was observed in summer season and minimum ( $118.65 \text{ cfu g}^{-1}$ ) in winter season. In microclimatic interaction effect, the bacterial count of soils of different forest ecosystem was ranged between ( $254.67$ - $33.67 \text{ cfu g}^{-1}$ ). The highest bacterial count was recorded Inban oak forest ( $F_3$ ) ( $254.67 \text{ cfu g}^{-1}$ ) in summer season which was statistically at par with mixed forest ( $F_2$ ) ( $253.00 \text{ cfu g}^{-1}$ ) in summer season and lowest in bare area ( $F_5$ ) ( $33.67 \text{ cfu g}^{-1}$ ) in winter season.

**Fig.1** Location map of different Ecosystems



**Fig.2** Climatograph of the year (Nov-May) 2015 - 2016



**Table.1** Ecology of selected sites studied in different ecosystem

Sr. No.	Botanical Name	Local Name	F <sub>1</sub>	F <sub>2</sub>	F <sub>3</sub>	F <sub>4</sub>	F <sub>5</sub>
<b>Trees</b>							
1	<i>Pinus roxburghii</i>	Chir	+				
2	<i>Quercus leucotrichophora</i>	Oak		+	+		
3	<i>Jacaranda mimosifolia</i>	Gulmohar		+			
4	<i>Toona ciliata</i>	Tooni		+			
5	<i>Dalbergia sissoo</i>	Shisham		+			
6	<i>Pyrus pashia</i>	Kainth		+			
7	<i>Albizia chinensis</i>	Siris		+			
8	<i>Grewia optiva</i>	Bhuel		+			
9	<i>Celtis australis</i>	Khirik		+			
10	<i>Salix alba</i>	White willow		+			
11	<i>Syzygium cumini</i>	Jamun		+			
<b>Shrubs</b>							
12	<i>Berberis lyceum</i>	Kashmal		+			
13	<i>Woodfordia floribunda</i>	Dhai	+	+	+		
14	<i>Bidens pilosa</i>	Kumber	+	+	+		
15	<i>Rosa species</i>	Kuja	+	+			
16	<i>Rubus ellipticus</i>	Akha	+	+			
17	<i>Cestrum nocturnum</i>	Rat ki rani		+			
18	<i>Sarcococca saligna</i>	Diun	+				
19	<i>Carissa carandas</i>	Karaunda	+	+			
20	<i>Myrsine africana</i>	Jhunjhara	+		+		
<b>Herbs</b>							
21	<i>Artemesia vulgaris</i>	Khardar	+				
22	<i>Calotropis procera</i>	Aak	+	+			
23	<i>Datura stramonium</i>	Dhatura	+				
24	<i>Fragaria vesca</i>	Wild strawberry	+	+	+		
25	<i>Thalictrum fendleri</i>	Meadow rue	+	+	+		
26	<i>Rumex nepalensis</i>	JungliPalak	+	+	+		
27	<i>Urticadioica</i>	Bichhubutti	+	+	+		
28	<i>Viola canescens</i>	Banafsa	+	+	+		
<b>Grasses</b>							
29	<i>Chrysopogon species</i>	Dholu	+	+	+		+
30	<i>Cynodondactylon</i>	Makora	+	+	+	+	+
31	<i>Eulaliopsis binata</i>	Bhabbar		+			
32	<i>Heteropogon contortus</i>	Lamb Sariala	+	+	+		
33	<i>Dicanthium spp</i>	Marvel grass		+	+		
34	<i>Themeda anathera</i>	-		+	+		
<b>Ferns</b>							
35	<i>Nephrolepis spp</i>	Boston fern					
36	<i>Cheilanthes argentea</i>	Silver fern					
<b>Agriculture crop</b>							
37	<i>Lens culinaris</i>	Masoor dal				+	

**Table.2** Seasonal variation in surface loading and surface thickness under different forest ecosystem in mid hills of Himachal Pradesh

Forest ecosystem	Surface loading ( $\text{kg m}^{-2}$ )			Surface Thickness (cm)		
	Winter	Summer	Mean	Winter	Summer	Mean
<b>Chir Pine forest (F<sub>1</sub>)</b>	1.33	2.16	1.75	2.31	3.52	2.91
<b>Mixed forest (F<sub>2</sub>)</b>	0.31	0.16	0.24	1.14	0.82	0.98
<b>Ban oak forest (F<sub>3</sub>)</b>	0.20	0.49	0.34	0.83	1.73	1.28
<b>Mean</b>	0.61	0.93		1.42	2.02	
<b>CD<sub>0.05</sub></b>	Forest (F): 0.04 Season (S): 0.03 Forest X Season (FxS): 0.06			Forest (F): 0.33 Season (S): 0.27 Forest X Season (FxS): 0.47		

**Table.3** Seasonal variation in soil microbial count under different forest ecosystem in mid hills of Himachal Pradesh

Forest ecosystem	Microbial count ( $\text{cfu g}^{-1}$ )								
	Bacteria ( $10^5$ )			Fungi ( $10^3$ )			Actinomycetes ( $10^5$ )		
	Winter	Summer	Mean	Winter	Summer	Mean	Winter	Summer	Mean
<b>Chir Pine forest (F<sub>1</sub>)</b>	128.21	195.33	161.77	2.10	2.92	2.51	6.68	8.47	7.57
<b>Mixed forest (F<sub>2</sub>)</b>	154.37	253.00	203.68	1.64	2.73	2.19	7.96	8.87	8.42
<b>Ban oak forest (F<sub>3</sub>)</b>	159.27	254.67	206.97	1.54	2.90	2.22	8.40	9.15	8.78
<b>Agriculture field (F<sub>4</sub>)</b>	117.75	164.33	141.04	1.46	2.42	1.94	5.11	6.10	5.61
<b>Bare area(F<sub>5</sub>)</b>	33.67	47.33	40.50	1.08	1.28	1.18	3.50	4.15	3.83
<b>Mean</b>	118.65	182.93		1.56	2.45		6.33	7.35	
<b>CD<sub>0.05</sub></b>	Forest (F): 3.89 Season (S): 2.46 Forest x Season (FxS): 5.49			Forest (F): 0.07 Season (S): 0.04 Forest x Season (FxS) :0.10			Forest (F): 0.10 Season (S): 0.07 Forest x Season (FxS): 0.15		

**Table.4** Seasonal variation in Soil Microbial Biomass under different forest ecosystem in mid hills of Himachal Pradesh

Forest ecosystem	Winter Season	Summer Season	Mean
<b>Chir Pine forest (F<sub>1</sub>)</b>	764.88	1878.77	1321.83
<b>Mixed forest (F<sub>2</sub>)</b>	817.83	2035.88	1426.86
<b>Ban oak forest (F<sub>3</sub>)</b>	825.24	2217.50	1521.37
<b>Agriculture field (F<sub>4</sub>)</b>	237.66	925.36	581.51
<b>Bare area(F<sub>5</sub>)</b>	133.76	255.66	194.71
<b>Mean</b>	555.87	1462.63	
<b>CD<sub>0.05</sub></b>	Forest (F): 56.36 Season (S): 35.65 Forest x Season (F x S): 79.70		

The actinomycetes population was found to be highest in the ban oak forest ( $F_3$ ) ( $8.78 \text{ cfu g}^{-1}$ ) followed by mixed forest ( $F_2$ ) ( $8.42 \text{ cfu g}^{-1}$ ) and chir pine forest ( $F_1$ ) ( $7.57 \text{ cfu g}^{-1}$ ). The lowest soil actinomycetes count of  $3.83 \text{ cfu g}^{-1}$  was observed under bare area ( $F_5$ ). The actinomycetes population in summer was found to be highest ( $7.35 \text{ cfu g}^{-1}$ ) and in winter to be lowest ( $6.33 \text{ cfu g}^{-1}$ ). In microclimatic interaction effect, the highest population of actinomycetes was found in ban oak forest ( $F_3$ ) ( $9.15 \text{ cfu g}^{-1}$ ) in summer season and lowest was found in bare area ( $F_5$ ) ( $3.50 \text{ cfu g}^{-1}$ ) in winter season.

The fungal population was observed to be the highest in chir pine forest ( $F_1$ ) ( $2.51 \text{ cells g}^{-1}$ ) and lowest soil fungal population was observed under bare area ( $F_5$ ) ( $1.18 \text{ cells g}^{-1}$ ). The summer season showed the highest soil fungal population of  $2.45 \text{ cells g}^{-1}$  and winter season showed the lowest of  $1.56 \text{ cells g}^{-1}$ .

The interaction of forest ecosystem X season on soil fungal count of mid hills of HP was found to be significant. The highest was found in chir pine forest ( $F_1$ )  $2.92 \text{ cells g}^{-1}$  in summer season which was statistically at par with ban oak forest ( $F_3$ )  $2.90 \text{ cells g}^{-1}$  in summer season, and found lowest in bare area ( $F_5$ )  $1.08 \text{ cells g}^{-1}$  in winter season.

Significantly higher bacterial and actinomycetes count was found in ban oak and mixed forest as compared to bare area were probably due to presence of higher organic carbon in the soils whereas fungal count was found to be higher in chir pine forest due to high acidic nature of soil ( $\text{pH}=5.36$ ).

The microbial count was higher in summer season than winter season due maximum air temperature in summer because microbial activities increase with increase in temperature as shown in Figure 2.

### **Microbial biomass**

Soil biomass significantly varied within the areas at different selected forest ecosystem in all the locations during winter and summer season 2015-2016 as shown in Table 4. Significantly maximum soil microbial biomass ( $1521.37 \mu\text{g C g}^{-1}$ ) was recorded under ban oak forest ( $F_3$ ). Whereas, minimum soil microbial biomass was recorded under bare area ( $F_5$ ) ( $194.71 \mu\text{g C g}^{-1}$ ). Significantly highest soil microbial biomass of  $1462.63 \mu\text{g C g}^{-1}$  was recorded during summer season and lowest of  $555.87 \mu\text{g C g}^{-1}$  during winter season.

The data presented in Table 4 further revealed that five different forest ecosystem (F) X seasons (S) interaction which also results a significant influence on soil microbial biomass distribution. Ban oak forest ( $F_3$ ) registered highest soil microbial biomass of ( $2217.50 \mu\text{g C g}^{-1}$ ) during summer season is in line with Vance *et al.*, (1987) who had reported  $61-2000 \text{ mg kg}^{-1}$  of soil biomass carbon under temperate and tropical forests.

However, minimum soil microbial biomass of ( $133.76 \mu\text{g C g}^{-1}$ ) was observed in winter season in bare area ( $F_5$ ) may be ascribed due to low return of organic material to such area. The low level of organic substrate for microbes and reduced mineralization rates due to unfavorable conditions like compaction, low soil moisture content and nutrient levels may be ascribed for reduced soil microbial biomass in bare area as compared to forest ecosystem.

Results obtained in this study clearly demonstrated that the amount of microbial biomass and count was observed in forest soil are different and generally higher in the forest floor. Our results also showed that in forest floor soil microbial biomass and count change in accordance with soil moisture, soil

temperature, organic matter content and structure of microbial community.

Seasonal changes in environmental conditions such as temperature and moisture facilitate the turnover of microbial biomass and consequently can perform an important role in controlling nutrient availability. Higher microbial biomass and count have usually been observed in summer season while lower values in winter. Because microbial biomass is used as indicator of soil activity, our findings suggest that under the very humid region of forest ecosystem, soil may be more active in summer than in winter.

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