Soil Respiration and Microbial Population in a Subtropical Mixed Oak Forest of Manipur, North-eastern India

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Abstract- Seasonal changes in in soil respiration and its relationship with microbial population was studied in sub-tropical mixed oak forest ecosystem of Kounu Hill, Senapati District, Manipur, located at a distance of 25 km from Imphal city which falls at 93°55´E longitude and 24°54´N latitude at an altitude of 941 m from mean sea level by using alkali absorption method .The rate of soil respiration was highest during the rainy season (345.98 mg CO_2 m^{-2} hr^{-1}) and minimum during the winter season (195.71 mg CO_2 m^{-2} hr^{-1}). The microbial population i,e bacterial and fungal population showed a significant positive relationship with the rate of soil respiration. The microbial population was maximum in rainy season and minimum during winter. Abiotic variables (i,e. soil temperature, rainfall, relative humidity, air temperature and soil moisture) also exhibited a positive significant relationship with the rate of soil respiration.

Index Terms- soil respiration, microbial population, mixed oak forest, bacteria and fungi.

I. Introduction

Soil respiration is an ecosystem process in which carbon dioxide is released from soil via root respiration, microbial decomposition of litter and soil organic matter, and faunal respiration.It has been considered as the second largest global carbon flux from terrestrial ecosystems to the atmosphere, and is the vital component of ecosystem respiration (Raich and Potter, 1995).Soil respiration is considered as an index of the metabolic activity of soil microorganisms. Soil microorganisms such as fungi and bacteria play a major role metabolizing the soil organic matter. Identifying the environmental factors that control soil respiration rate, and their effects on CO2 emission rates, is a necessary step in assessing the potential impacts of environmental change. Soil respiration rate are largely dependent upon soil temperature and moisture conditions (Singh and Gupta, 1977). Seasonal changes in soil microclimate play an important role in defining seasonal differences in soil respiration rate .Several workers (Raich and Schlesinger 1992; Singh and Gupta 1977; Laishram et al.2002; Bijayalaxmi and Yadava 2008) studied soil respiration and its relationship with abiotic factors in different forest ecosystems but limited information is available on soil respiration and microbial population from northeastern region of India (Pandey et al..2010;Mohanty and Panda 2011)).Therefore, the present study was carried out to investigate the seasonal change of soil respiration and its relationship to microbial population and abiotic variables in a subtropical mixed Oak forest of Manipur.

II. Materials and methods

The study site is located at a distance of 25 km from Imphal city which falls at 93°55´E longitude and 24°54´N latitude at an altitude of 941 m from mean sea level. The climate of the area is monsoonic with warm moist summer and cool dry winter. The mean monthly maximum temperature ranges from 22 to 32.7 °C and the mean monthly minimum temperature ranges from 4.9 to 22.8 °C. Average annual rainfall of the area is 1131.8 mm. The forest is dominated by *Castanopsis indica , Lithocarpus dealbata , L. fenestrata, Quercus polystachya , Quercus. serrata and Schima wallichii.*

The soil samples were collected from the upper layer of 0-10 cm in depth at monthly interval and brought to the laboratory for further analysis. The soil samples were sieved (< 2mm) to remove stones, roots etc.Soil texture was analysed by pipette methods.A soil thermometer was used to determine soil temperature.The soil moisture was measured by gravimetric method (oven dry at 105°C till constant weight).Soil pH (1:2.5 water suspension) was determined by a pH meter. Soil organic carbon by Walkley Black method,total nitrogen by Kjeldahl method and available P were determined by Brays and Kurtz method

Soil respiration rate was measured by alkali absorption method using open-ended aluminium cylinders(13 cm diameter and 25 cm tall) inserted 10 cm deep into the soil .Ten identical cylinders were used. Fifty ml of 0.25 N NaOH solutions in each cylinder was maintained for 24 hr and all green vegetation inside the cylinder was removed. After 24 hr the alkali was titrated with 0.25N HCL solution using phenolphthalein as an indicator. CO_2 absorbed from the soil was calculated using the formula proposed by Anderson and Ingram (1993): $V \times N \times 22 = CO_2$ mg**,** where V=Volume of HCL, N=Normality of HCL.

For estimation of soil microorganisms, serial dilution (suspension) plating method was used as described by Parkinson et al (1971). The isolation of bacteria and fungi from soil samples was initiated by taking 10 g freshly collected ground soil in 250 ml Erlenmeyer flasks containing 100 ml distilled water and shaken for 15 min on a horizontal mechanical shaker.The suspension was further diluted to 10^{-4} and then to 10^{-5} using sterile distilled water.1 ml aliquot of 10^{-4} dilution for fungi and 10^{-5} dilution for bacteria was inoculated .20 ml molten and cooled (40°C) Martin's agar(Martin,1950),Thornton's agar(Thornton,1922) media was poured separately into each petridish for isolation of fungi and bacteria respectively.The dishes were incubated at 25±1° C for fungi and 30 ±1°C for bacteria.The microbial colonies were counted after 2 and 7 days of incubation for bacteria and fungi.The average number of colony forming units (CFUs) was calculated as counts g^{-1} dry soil.

Correlation and linear regression analyses were done to assess the relationship between soil respiration rate and soil biotic and abiotic variables. ANOVA was also used to analyse the data.

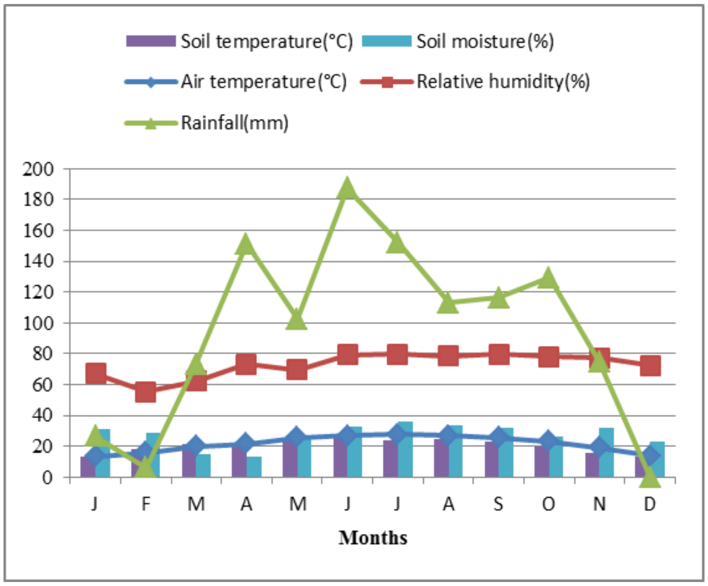


Fig 1.Monthly variation in abiotic variables

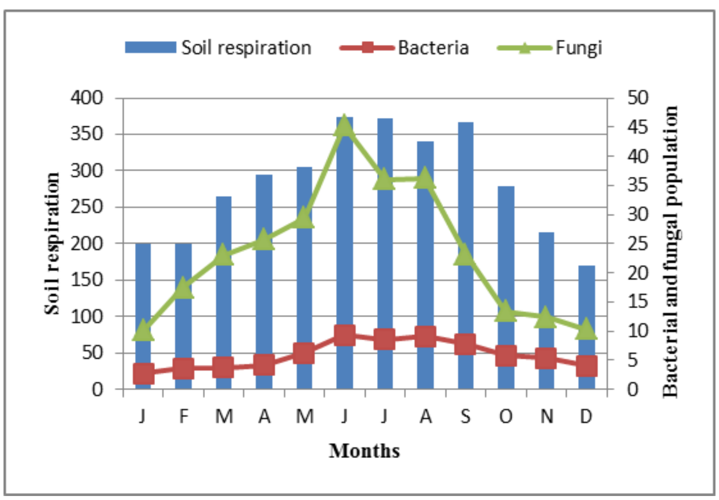


Figure 2. Monthly variation of soil respiration,bacterial population ,fungal population

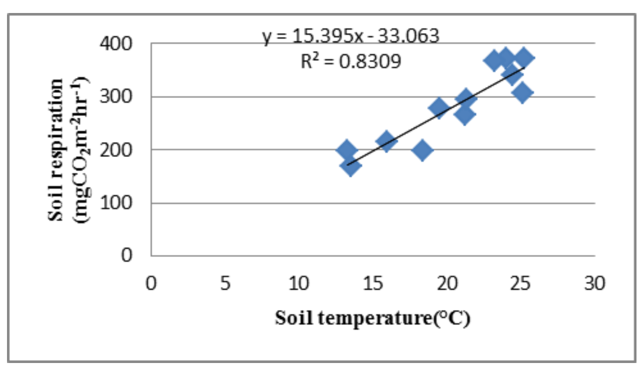
Results:

The soil is clayey loam in texture (sand 35 %, silt 24 % and clay 41 %).The soil temperature ranges from 13.26 to 25.2°C ,soil moisture ranged from 18.57 to 33.33 % , soil pH ranged from 4.4 - 5,bulk density 1.32-1.58 g cm^{-3}, soil organic carbon 2.1-3.2 %, soil total N 0.168-0.39 %, soil available phosphorus 0.03-0.06 %,

The rate of soil respiration ranged from 169.24 mg CO_2 m^{-2} hr^{-1} to 373.20 mg CO_2 $m^{-2}hr^{-1}$ in different months throughout the year. It was highest in the rainy season (June to October) followed by summer (March to May) and winter (November to February) .The analysis of variance (ANOVA) indicated a significant differences (p<0.001) in the rate of soil respiration among different seasons.The maximum bacterial and fungal population was recorded in rainy season followed by summer season and minimum during winter season .Bacterial counts were always high as compared to fungal population. The rate of soil respiration was significantly positively correlated with soil temperature (r=0.91,p<0.01), soil moisture (r=0.60,p<0.05), relative humidity (r=0.60,p<0.05), air temperature (r=0.75,p<0.01) and rainfall (r=0.88,p<0.01).A significant positive correlations were observed between soil respiration rate and bacterial (r=0.87,p<0.01),fungal (r=0.92,p<0.01) population. Figure 2 shows the seasonal variation of soil respiration, bacterial population and fungal population. Carbondioxide production from soil and its monthly fluctuation is somewhat similar to the population trend of bacteria and fungi.

Table 1.Abiotic variables and physico-chemical characteristics of soil

Abiotic variables			
Soil temperature(°C)		20.43	
Soil moisture(%)		27.40	
Rainfall(mm)		94.31	
Relative humidity(%)	72.72		
Air temperature(°C)	23.65		
Soil physico- chemical characteristics			
Texture			
Sand(%)		35	
Silt (%)		24	
Clay (%)		41	
Bulk density(g cm^{-3})		1.40	1.40
Soil pH		4.4-5	
Soil organic carbon (%)		2.1-3.2	
Soil total N (%)		0.168-0.39	
Soil available P (%)		0.03-0.06	



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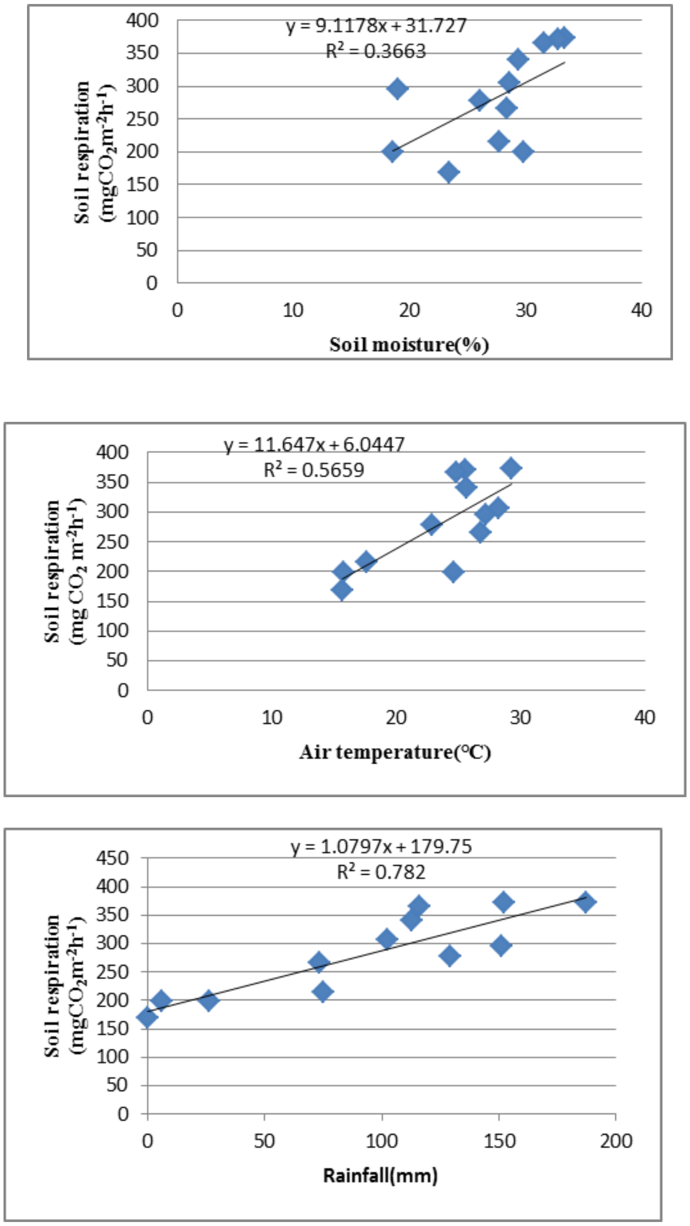

Fig 3.Regression analysis of soil respiration and abiotic variables

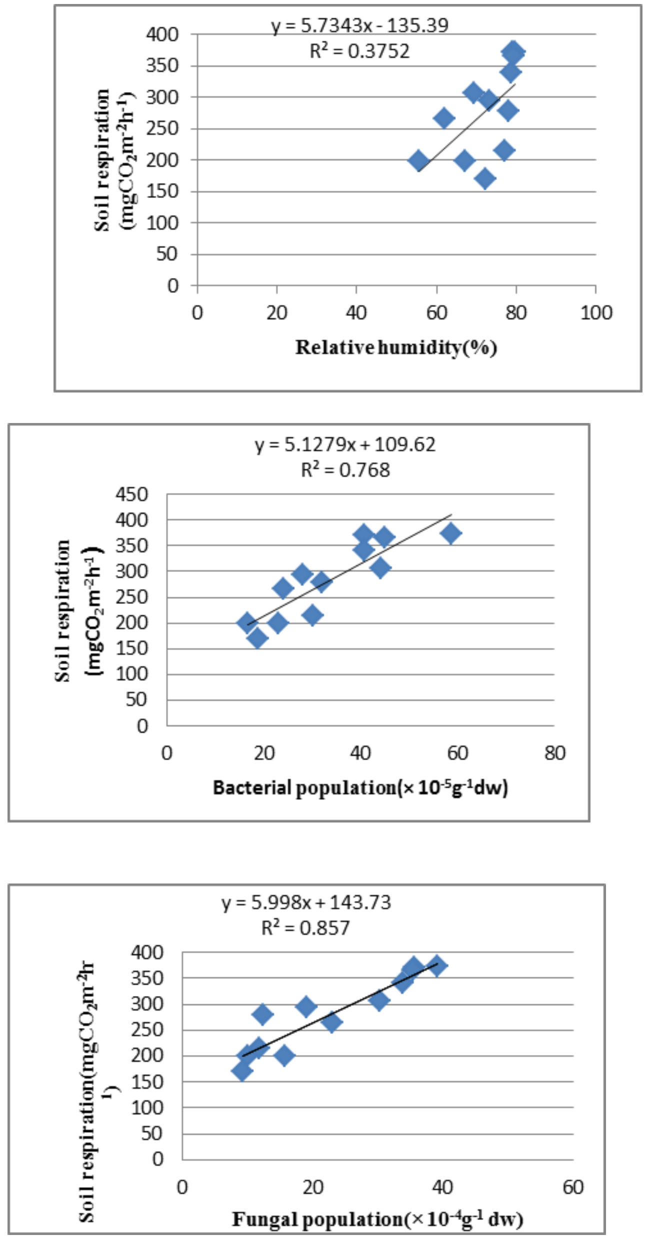

Figure 4. Regression analysis of soil respiration rate and biotic variables

III. Discussion

The rate of soil respiration was highest in rainy season and minimum in winter season. Minimum rate of soil respiration in winter seasons may be due to low moisture content, temperature and as a result of decreased microbial population. In rainy season, due to high soil moisture and temperature, the soil microorganisms became more active causing an enhancement in the decomposition of litter materials and finally contributing to more CO_2 emission from the soil. Table 2 compares the ranges of soil respiration values estimated in the present study with that of different Oak forest ecosystem of the world. The variation in soil respiration rate reported by different workers could be influenced somewhat by used methods, volume of alkali solution, different strength, exposure time and time intervals (Gupta and Singh, 1977).

Table 2: Comparison of soil respiration rate (mg CO_2 m^{-2} hr^{-1}) in different Oak forest ecosystem of the world.

Forest type	Country	Soil respiration rate	Authors
Oak	USA	156-193	Witcamp(1966)
Mixed Oak	Belgium	20-15	Froment(1972)
Mixed Oak	Japan	161.42	Kirita(1971)
Oak	India	368.00-634.23	Laishram et al (2002)
Mixed Oak	India	168.68-193.74	Bijayalaxmi(2005)
Mixed Oak	India	169.24-373.2	Present Study

(2005) Present study

Soil respiration is closely related with temperature and moisture.This is because that the biological activities in soil are strongly affected by the environmental factors. A significant positive correlation of soil CO_2 with soil moisture and temperature has been reported by several workers in different forest ecosystems (Reiners,1968; Singh and Gupta 1977;Laishram et al..,2002;Bijayalaxmi and Yadava,2008).Fig 3 shows that soil respiration rate is positively correlated with soil temperature and also positively correlated with air temperature. This means that the difference of soil soil respiration rate in different Oak forest ecosystem of the world is mainly caused by the variation of temperature .So, it is expected that there would be an increase of soil respiration in forest with global warming. Other abiotic factors like rainfall and relative humidity also shows positive significant correlation with soil respiration.Monthly fluctuation of soil carbondioxide emission and microbial population is somewhat similar in figure 2. Activity of the microorganisms in soil are frequently dependent on environmental factors such as temperature, moisture, vegetation structure and nutrient availability.The peak season of the microbial population was found in rainy season may be due to favourable soil moisture and temperature conditions which enhance microbial activity and decomposition. But minimum microbial population during winter in the present study may be due to water stress and low soil temperature which slowed down microbial activity and organic matter decomposition and thus resulted in a low microbial population. In this experiment, a significant positive correlation was found between soil respiration rate and populations of bacteria and fungi. Significantly positive correlation between soil respiration rate and population of bacterial, fungal has been reported by several workers (Pandey et al., 2010; Tiwari et al., 1996) .The present study concludes that soil respiration rate is strongly influenced by seasons and positively correlated with biotic (bacteria and fungi) and abiotic variables. So, soil respiration is considered as one of the indicator for microbial activity in soil.

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