

Microbial population, fungal biomass and CO₂ evolution in maize (*Zea mays* L.) field soils

MAMTAJ S. DKHAR and R.R. MISHRA

Department of Botany, School of Life Sciences, North-Eastern Hill University, Shillong — 793014, India

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Summary CO₂ evolution, fungal biomass and microbial population of two maize field soils differing in agricultural systems *viz.*, permanent agriculture on plain lands in valleys and 'slash and burn' type of shifting agriculture, were estimated at monthly intervals for one crop cycle. The results showed significant positive correlation among CO₂ evolution, fungal biomass, microbial population, organic C and total N. There was significant positive correlation between bacterial population and moisture content in both the agricultural systems. Microbial population and CO₂ evolution were always higher in the soils of permanent agriculture as compared to that of 'slash and burn' type of shifting agriculture.

Introduction

The estimation of soil respiration either as O₂ uptake or CO₂ evolution is the most widely used measure of soil microbial activity^{11,13,32}. This estimation provides insights into the rates of organic matter breakdown and mineralization⁵. According to Stotzky²⁰ changes in CO₂ evolution and microbial biomass are related to each other. Fungi play an important role in the mineralization processes in the soil and in many soils, the fungal biomass greatly exceeds the biomass of other microorganisms²¹. Singh and Gupta²² have reviewed various methods for measurement of soil respiration in natural conditions and concluded that major governing factors are temperature and soil moisture and these are positively correlated with the soil respiration. Upadhyaya *et al.*²⁷ reported that soil temperature and soil moisture were related linearly with CO₂ evolution.

For the better understanding of the activity of soil microbes in soil, the measurement of respiratory activity in relation to microbial biomass as well as the environmental factors is of great importance. In this study, experiments were carried out to relate indices of CO₂ evolution to microbial population and fungal biomass and physico-chemical characters of two maize field soils differing in agricultural systems *viz.*, permanent agriculture on plain lands in valleys and 'slash and burn' type of shifting agriculture on slopes of North-Eastern region of India.

Materials and methods

The two maize fields were permanent agriculture on plain lands in valleys and 'slash and burn' type of shifting agriculture on hill slopes. The study was carried out for one crop cycle of maize during May to September. The surface soil samples (0–10 cm) were collected from each study site at monthly intervals and the following studies were made:

The amount of CO₂ evolved from the soil was measured by trapping with 0.1 N KOH solution and titrated with 0.1 N HCl solution using phenolphthalein as an indicator. Three replicates were taken.

Jones and Mollison's⁹ agar film technique as modified by Thomas *et al.*²⁴ was followed for the determination of fungal biomass. The soil plate method³⁰ using rose-bengal agar medium¹² was used to estimate number of fungal propagules. Inoculated Petri dishes were incubated at 25°C for five days. Number of viable bacteria were estimated by the dilution plate method²⁸ using nutrient agar medium¹⁰. The cultures were incubated at 30°C for 24 hours. pH was measured in a 1:5 soil water suspension using electric digital pH meter. Moisture content of the soil was measured by drying soil in an oven at 105°C for 24 hours. The soil used in the analyses of organic carbon (C) nitrogen (N), phosphorus (P) and potassium (K) was air dried and ground to pass through a 0.2 mm sieve. Soil organic carbon was determined by rapid titration method²⁹. Total N and P were determined by macro Kjeldahl's method and molybdenum blue method respectively. K was extracted in ammonium acetate buffer (pH = 7.0) and measured using a flame photometer².

Results and discussion

The monthly variations in the physico-chemical characters of the two maize field soils are given in Fig. 1. The soil of permanent agriculture was rich in the organic C, moisture content, N, P and K throughout the study period. The low nutrient level in 'slash and burn' type of shifting agricultural system was due to burning and removal by rapid run off from the hill slopes¹⁸.

The amount of CO₂ evolved was higher in the soil of permanent agriculture. A positive correlation between CO₂ evolution, microbial population and fungal biomass was observed in both the agricultural systems as also found by Ross¹⁷. It appears that the microorganisms were

Table 1. Physico-chemical characters of two maize field soils

Months	Temperature (°C)	pH	Moisture content (%)	Organic C (%)	N (%)	P (%)	K (%)
<i>Permanent agricultural system</i>							
May	20	6.4	30.0	2.55	0.22	0.018	0.20
June	22	6.1	25.3	0.75	0.17	0.019	0.10
July	28	5.5	32.0	3.48	0.37	0.027	0.08
August	25	7.2	30.0	2.85	0.22	0.021	0.07
September	23	7.9	30.0	2.91	0.25	0.013	0.10
<i>'Slash and burn' agricultural system</i>							
May	32	5.5	14.0	1.00	0.04	0.011	0.03
June	35	5.0	12.4	0.55	0.02	0.012	0.02
July	40	4.0	19.3	1.20	0.10	0.019	0.05
August	38	6.9	18.0	1.02	0.05	0.013	0.06
September	35	5.6	18.0	1.05	0.10	0.010	0.06

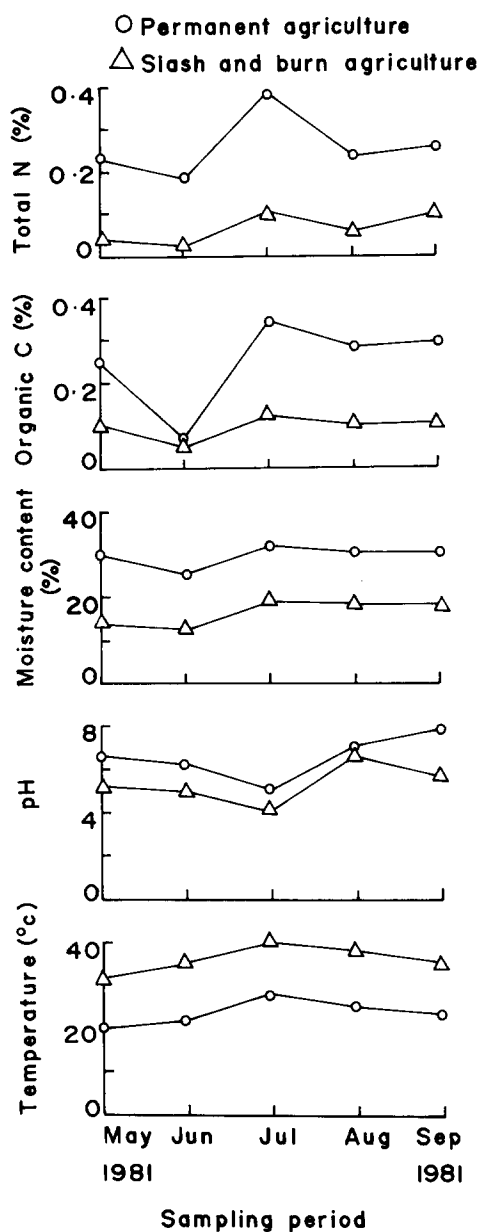


Fig. 1. Monthly variation in physico-chemical characteristics of two maize field soils during the study period (May–September).

the most important contributor towards the CO₂ evolution. CO₂ evolution was maximum in the month of July (Fig. 2); the higher rate reflects the favourable effect of soil moisture and moderate temperature on microbial activity⁸. Tesarova and Glosa²⁵ have shown that soil moisture content was of greater importance than the temperature in controlling

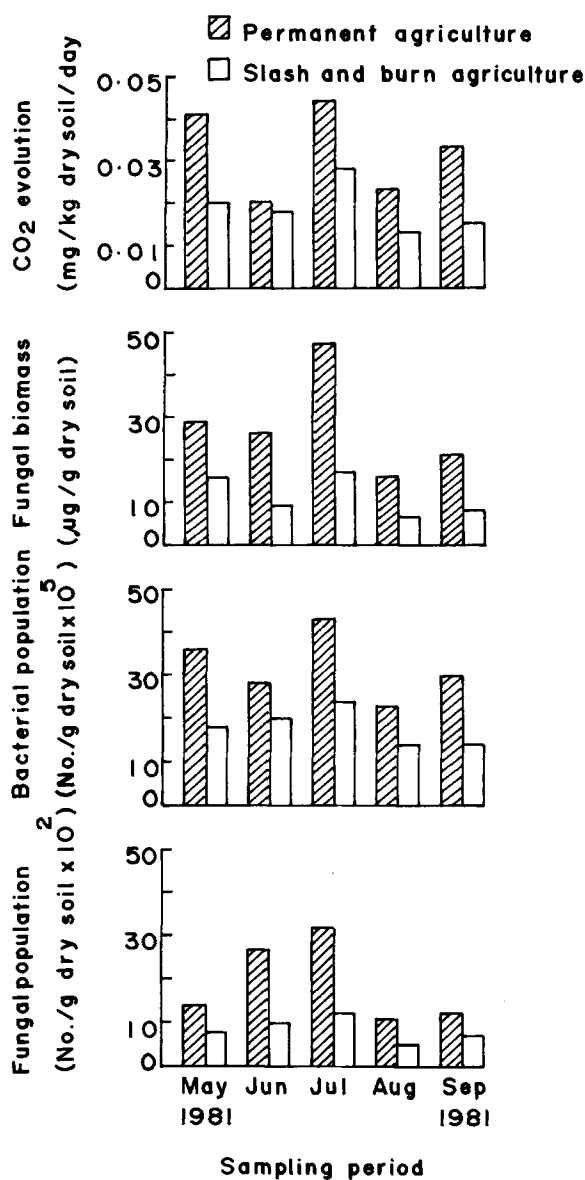


Fig. 2. Monthly variation in CO₂ evolution, fungal biomass, bacterial and fungal populations in two maize field soils during the study period (May—September).

CO₂ evolution from soil. Witkamp³¹ and Anderson¹ have indicated that temperature exerts a decisive influence on CO₂ metabolism of the soil when there is sufficient water supply. We observed similar results in the 'slash and burn' type of shifting agricultural system but not with the permanent agricultural system. There was a slight increase in the microbial population and CO₂ evolution after the harvest of the maize plants

Table 2. Correlation coefficient (r) values among the CO₂ evolution, microbial populations, fungal biomass and physico-chemical characters of two maize field soils

	Permanent agricultural practice	'Slash and burn' agricultural practice
CO ₂ evolution vs fungal population	0.9985**	0.8366**
CO ₂ evolution vs fungal biomass	0.8876**	0.6605
CO ₂ evolution vs bacterial population	0.9921**	0.9055**
CO ₂ evolution vs moisture content	0.8656**	0.1789
CO ₂ evolution vs organic C	0.7955*	0.3099
CO ₂ evolution vs total N	0.7803*	0.8895**
CO ₂ evolution vs temperature	0.1264	0.9241**
Fungal population vs fungal biomass	0.8011*	0.9867**
Fungal population vs bacterial population	0.1489	0.1292
Fungal population vs moisture content	0.4411	0.8366*
Fungal biomass vs moisture content	0.4213	0.9140**
Bacterial population vs moisture content	0.6846*	0.6558*

*, ** Significant at 0.05 and 0.01 probability levels.

in the month of September which may be due to the increase substrate availability in the form of dead and dying plant remains (Fig. 2). Positive correlations were found between the CO₂ evolution, microbial population and some of the physico-chemical characters of the soils (Table 2). The positive correlation between the CO₂ evolution and soil organic C and total N contents has also been reported¹⁸.

A comparison of the microbial population and its activity (Fig. 2) with physico-chemical characters (Table 1) of the soil showed that population level and its activity were a function of the soil temperature, moisture content, organic C, N, P and K of the soil. The increased rate of CO₂ evolution found at the higher temperature in both the soil systems during the month of July may have been caused by higher C, N, P and moisture which resulted in a higher microbial population and biomass. Our results showed that low pH values were associated with the higher microbial activity and the CO₂ evolution. Mikola and Komppula¹⁴ also reported that CO₂ evolution was higher in the acidified peat which was ascribed to the increase in bacterial and fungal populations^{15,19}. A positive correlation (Table 2) was found between bacterial population and soil moisture content^{4,26}.

Fungal biomass was positively correlated with soil moisture as also noted by Soderstrom²³. The peak of fungal biomass was observed in July (Fig. 2) when moisture content was also at its maximum level. Soil moisture, therefore, appears to be an important factor in determining the seasonal pattern of soil fungal biomass through direct as well as indirect effects. This has earlier been suggested by several authors^{7,23}. Fungal biomass increased slightly after the harvest (Fig. 2.). This increase in the

biomass may also be due to changed growth rate of fungal mycelium²³.

From our results it could be concluded that soil moisture is important factor in governing the respiratory activity of the maize field soils. The importance of soil moisture has been well documented for many different soils^{3,6,16}. The results indicate that there were relationships among the CO₂ evolution, microbial population, fungal biomass and physico-chemical characters like soil organic C, N, P and K. The permanent agricultural system always harboured higher rates of CO₂ evolution, microbial population and fungal biomass, most possibly due to higher concentration of nutrients and sufficient availability of soil moisture.

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