Plant and Soil 99, 277–283 (1987). Ms. 5293

Microbial population, fungal biomass and CO_2 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

Received January 1983. Revised October 1986

Key words Bacteria CO_2 evolution Fungi Fungal biomass Maize (*Zea mays* L.)

Summary CO_2 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 CO_2 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 CO_2 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 O_2 uptake or CO_2 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 mineralization[5]. According to Stotzky[20] changes in CO_2 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 microorganisms[21]. Singh and Gupta[22] 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 CO_2 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 CO_2 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 CO_2 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's[9] agar film technique as modified by Thomas *et al.*[24] was followed for the determination of fungal biomass. The soil plate method[30] using rose-bengal agar medium[12] 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 method[28] using nutrient agar medium[10]. 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 method[29]. 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 photometer[2].

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 slopes[18].

The amount of CO_2 evolved was higher in the soil of permanent agriculture. A positive correlation between CO_2 evolution, microbial population and fungal biomass was observed in both the agricultural systems as also found by Ross[17]. 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 (%)
Permanent agricultural system							
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
'Slash and burn' agricultural system							
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

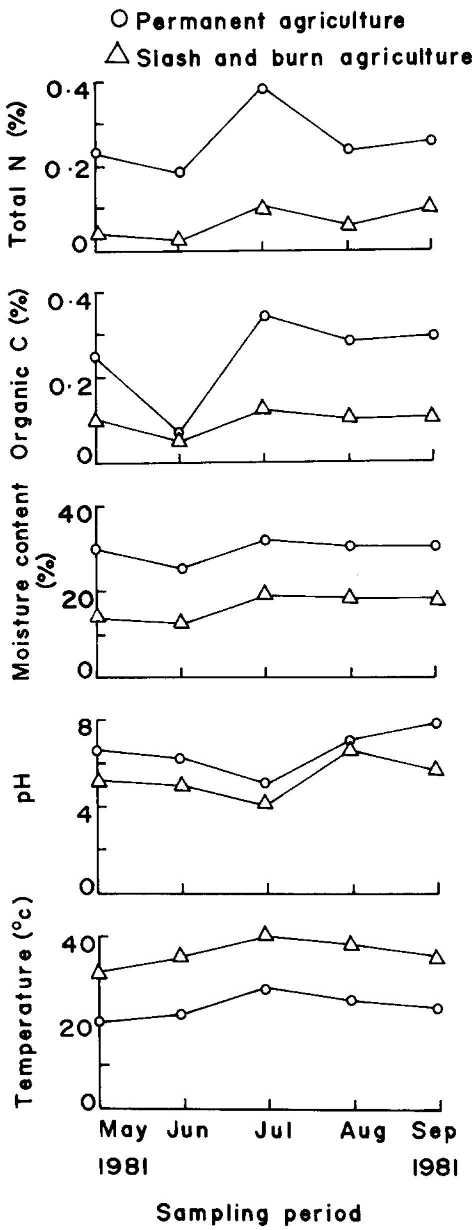

Fig. 1. Monthly variation in physico-chemical characteristics of two maize field soils during the study period (May–September).

the most important contributor towards the CO_2 evolution. CO_2 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 activity[8]. Tesarova and Glosa[25] have shown that soil moisture content was of greater importance than the temperature in controlling

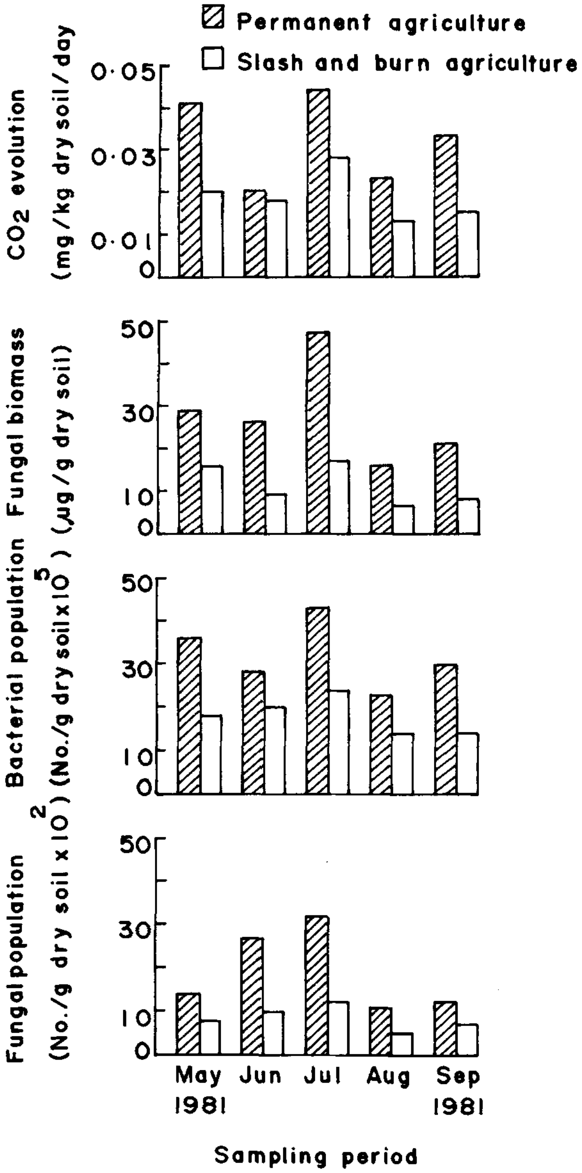

Fig. 2. Monthly variation in CO_2 evolution, fungal biomass, bacterial and fungal populations in two maize field soils during the study period (May—September).

CO_2 evolution from soil. Witkamp[31] and Anderson[1] have indicated that temperature exerts a decisive influence on CO_2 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 CO_2 evolution after the harvest of the maize plants

Table 2. Correlation coefficient (r) values among the CO_2 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 CO_2 evolution, microbial population and some of the physico-chemical characters of the soils (Table 2). The positive correlation between the CO_2 evolution and soil organic C and total N contents has also been reported[18].

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 CO_2 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 CO_2 evolution. Mikola and Komppula[14] also reported that CO_2 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 Soderstrom[23]. 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 mycelium[23].

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 CO_2 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 CO_2 evolution, microbial population and fungal biomass, most possibly due to higher concentration of nutrients and sufficient availability of soil moisture.

Acknowledgement One of the authors Mamtaj S Dkhar is thankful to Council of Scientific and Industrial Research, New Delhi, for financial assistance.

References

1 Anderson J M 1973 Carbon-dioxide evolution from two temperate deciduous woodland soils. J. Ecol. 10, 361–78.

2 Allen S E (Ed.) 1974 Chemical analysis of ecological materials. Blackwell Scientific Publications, Oxford pp 565.

3 Bunnel F L, Tait D E N, Flanagan P W and Cleve M V 1977 Microbial respiration and substrate weight loss. 1. A general model of the influence of abiotic variables. Soil Biol. Biochem. 9, 33–40.

4 Cutler D W, Crump L M and Sandon H 1922 A quantitative investigation of the bacterial and protozoan fauna. Philosophical Transactions of the Royal Society Series B 211, 317–347.

5 Cleve K V, Coyne P I, Goodwin E, Johnson C and Kelley M 1979 A comparison of four methods for measuring respiration in organic material. Soil Biol. Biochem. 2, 237–246.

6 Douglas L A and Tedrew J C F 1959 Organic matter decomposition rates in Arctic soils, Soil Sci. 88, 305–12.

7 Dowding P and Widden P 1974 Some relationships between fungi and their environment in Tundra regions. *In* Soil Organisms and Decomposition in Tundra. Eds A J Holding, O W Heal, S F Maclean Jr and P W Flanagan. pp 123–150. Tundra Biome Steering Committee, Stockholm, Sweden.

8 Gupta S R and Singh J S 1981 Soil respiration in a tropical grasslands. Soil Biol. Biochem. 13, 261–268.

9 Jones P C T and Mollison J E 1948 A technique for the quantitative estimation of soil microorganisms. J. Gen. Microbiol. 2, 54–69.

10 Johnson L F and Curl E A 1972 Methods for the Research on Ecology of soil borne plant pathogens (Minneopolis Burges Publication Co) pp 247.

11 Kucera C L and Kirkham D R 1971 Soil respiration studies in tall grass prairie in Missouri. Ecology 52, 912–15.

12 Martin J P 1950 Use of acid, rose bengal and streptomycin in the plate method for estimation of soil fungi. Soil Sci. 69, 215–232.

13 Macfadyen A 1973 Inhibitory effects of carbon dioxide on microbial activity in soil. Pedobiologia 13, 140–149.

14 Mikola J and Komppula J 1981 Respiratory activity of milled peat: a rapid method of measurement and observation on the effects of moisture, temperature, pH and peat quality. Soil Sci. 131, 156–162.

15 Roberge M R and Knowles R 1966 Microbial populations in a black spruce humus fertilized with urea. Woodland Research Index. Pulp paper Research Institute, Canada 180, pp 27.

16 Reiners W A 1968 Carbon dioxide evolution from the floor of three Minnesota forests. Ecology 39, 471–83.
17 Ross D J 1973 Some enzymes and respiratory activities of tropical soils from New Hebrides, Soil Biol. Biochem. 5, 559–567.
18 Ramakrishnan P S and Toky O P 1981 Soil nutrient status of hill agro-ecosystems and recovery pattern after slash and burn agriculture (jhum) in North-Eastern India. Plant and Soil 60, 41–64.
19 Schalin I 1967 On the effect of nitrogen fertilization on the bacteria and micro-fungi in humus layer, Silva Fenn 3, 1–12.
20 Stotzky G 1960 A simple method for the determination of the respiratory quotient of soils. Can. Microbiol. 6, 439–452.
21 Soderstrom B 1977 Vital staining of fungi in pure cultures and in soil with fluorescein diacetate. Soil Biol. Biochem. 9, 59–63.
22 Singh J S and Gupta S R 1977 Plant decomposition and soil respiration in terrestrial ecosystems. Bot. Rev. 43, 449–528.
23 Soderstrom B E 1979 Seasonal fluctuations of active fungal biomass in horizons of a podzolized pine forest soil in Central Sweden. Soil Biol. Biochem. 11, 149–154.
24 Thomas A, Nicholas D P and Parkinson D 1965 Modifications of the agar-film technique for assaying lengths of mycelium in soil. Nature, London 205, 105.
25 Tesarova M and Glosa J 1976 Total carbon dioxide output from alluvial soils with two types of grassland communities. Pedobiologia 16, 364–72.
26 Tate R L and Richard T R 1980 Variation in microbial activity in histosols and its relationship to soil moisture. Appl. Environm. Microbiol. 40, 313–317.
27 Upadhyaya S D, Siddiqui S A and Singh V P 1981 Seasonal variation in soil respiration of certain tropical grassland communities. Trop. Ecol. 22, 157–161.
28 Waksman J H 1922 A method of counting of the numbers of fungi in the soil. J. Bot. 7, 339–341.
29 Walkley A and Black I A 1934 An examination of the Degtjaredd method for determining soil organic matter and a proposed modification of the chromic acid titration method. Soil Sci. 37, 29–38.
30 Warcup J H 1950 The soil plate method for isolation of fungi from soils. Nature, London 166, 117–118.
31 Witkamp M 1966 Rates of carbon dioxide evolution from the forest floor. Ecology 47, 492–494.
32 Wagner G M 1975 Microbial growth and carbon turnover. *In* Soil Biochemistry. Eds E A Paul and A D Mclaren. pp 269–305, Marcel Dekker, New York.