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Effect of long term manuring and fertilization on carbon mineralization in soils of finger millet-maize cropping system in Alfisols

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Abstract
Quantitative information on carbon (C) mineralization of soil under different long term nutrient management is essential for better assessment of easily hydrolyzable C and loss of C from soil. With an aim to evaluate the differences in C mineralization due to long term fertilization and manuring treatments, a laboratory incubation study was conducted with soils (0-15 cm depth), collected from 33 years old finger millet-maize cropping system which involved application of 100% N, 100% NP, 50% NPK, 100% NPK, 150% NPK, 100% NPK + FYM (farmyard manure), 100% NPK + lime, control and uncultivated fallow land. Long-term application of fertilizers and manures significantly ($p<0.05$) influenced C mineralization in soil. Long term integrated application of chemical fertilizers and organic manure in soil resulted in higher cumulative carbon mineralization, basal soil respiration (BSR), microbial and mineralization quotients. A judicious FYM application strategy through integration of both organic and inorganic sources is essential for improving and maintaining soil organic C pool.

Keywords: Carbon, mineralization, cumulative mineralization, basal soil respiration, microbial quotient, mineralization quotient, long term fertilization, farm yard manure

1. Introduction

Soil organic matter is a major terrestrial pool for C, N, P and S and the cycling and availability of these elements are constantly being changed by microbial immobilization and mineralization (Liu *et al*., 2006) [18]. The rate of organic C mineralization and the equilibrium levels that can be maintained in different soils are crucial measures of potential soil productivity (Riffaldi *et al*. 1996) [26]. Mineralization of organic matter and accumulation of carbon in soil is affected by several environmental factors and management practices; further rate of mineralization has a strong relationship with quantity and quality of both applied and in situ organic matter of soil (Balkcom *et al*., 2009) [3].

The turnover rate of different fractions of soil organic carbon determines the potential carbon storage and loss in the soil. The oxidation of easily mineralizable pool of organic C is mainly responsible for flux of CO_2 from soil to environment (Iqbal *et al*., 2009) [13]. Crop productivity substantially influences soil C turnover by differential C inputs, thus altering microbial activities responsible for C mineralization. Microbial indices (ratios between microbiological parameters) are often used to evaluate microbial eco physiology indicating an inter-linkage between cell-physiological functioning and environmental factors (Anderson, 2003) [2]. Most of the studies on C mineralization are based on decomposition of added C to a soil of uniform C status, whereas, the present study determined the C mineralization in soil that has been differentially fertilized for 33 years under same set of agronomic/cultural practices.

Several studies have reported build-up of SOC as a result of long-term application of fertilizers and organic manure (Benbi, 2015) [4]. However, the mineralization potential of accrued C has not been adequately studied; consequently the underlying reasons for the development of SOC in long-term experiments are poorly understood. We hypothesized that the C mineralization in soil will be differently influenced by stabilized forms of SOC and newly added C through organic manure. Therefore, the specific objective of the present study was conducted to examine mineralization of SOC accumulated as a result of long-term application of fertilizers and manures to soil under finger millet-maize cropping system.

2. Material and Methods

2.1 Location of the study area

The long term fertilizer experimental (LTFE) site in the Zonal Agricultural Research Station, GKVK campus of University of Agricultural Sciences, Bangalore, located in Eastern Dry Zone of Karnataka .The experiment was started during 1986-87 with two cropping sequence of finger millet during *Kharif* followed by hybrid maize during Rabi-summer.

2.2 Experimental design and treatment details

The experiment consists of eleven treatments which are replicated four times in a Randomized Complete Block Design. However, for the present study only three replications, eight treatments and one more additional treatment of fallow land adjacent to the LTFE site were considered. Each plot dimension is 16 m x 9 m (144 m^2). The details of experiment, treatments, recommended dose of fertilizers for the study crops, sources of fertilizers are given in Table 1.

Table 1: Details of the treatments and fertilizer sources

Treatment	NPK dosage (kg ha^{-1})		Fertilizer Source
	Finger millet	Hybrid maize	
T_1: Control	00-00-00	00-00-00	----------
T_2: 100% N	100-00-00	100-00-00	Urea
T_3: 100% NP	100-22-00	100-32-00	Urea, SSP
T_4: 50% NPK	50-11-21	50-16-41	Urea, SSP, MOP
T_5: 100% NPK	100-22-42	100-32-82	Urea, SSP, MOP
T_6: 150% NPK	150-33-63	150-48-123	Urea, SSP, MOP
T_7: 100% NPK + FYM	100-22-42	100-32-82	Urea, SSP, MOP
T_8: 100% NPK + FYM + lime	100-22-42	100-32-82	Urea, SSP, MOP, lime
T_9: Fallow land	00-00-00	00-00-00	----------

Lime was applied based on lime requirement following the method given by Shoemaker *et al*. (1961) [29] during *kharif* season. Well decomposed farmyard manure (FYM) at the rate of 15 t ha^{-1} has been incorporated every year into the soil 10-15 days prior to sowing of the *kharif* crop. Transplanted finger millet was grown during *Kharif* followed by hybrid maize during *Rabi-summer* with protected irrigation.

2.3 Carbon mineralization

Soil samples were collected in the LTFE plots treatment wise after the harvest of maize crop (2020) and used for the carbon mineralization study. Carbon mineralization was studied in the laboratory by conducting aerobic incubation under controlled conditions. 200 grams of soil was wetted to 50% water-filled pore space and placed in a 1000 mL conical flask along with vials containing 10 mL of 0.1M NaOH to trap evolved CO_2 and incubated for 32 days at 25 ± 1 °C. Three flasks without soil were kept as blank. Alkali traps were replaced at 1, 2, 3, 4, 5, 7, 9, 11, 14, 17, 20, 23, 26, 29 and 32 days after incubation. Evolved CO_2 was determined by titrating the alkali in the traps with 0.1 M HCl using phenolphthalein as indicator. The CO_2 evolved in 32 days of incubation was used as cumulative mineralization (CO_2-C_{cum}). Basal soil respiration (BSR), an estimate of potential microbial activity, was calculated as the linear rate of respiration during 29th to 32nd day of incubation because during that period the soil reached a relatively constant hourly CO_2 production rate. Microbial indices (microbial quotient and mineralization quotient) were calculated by using the formulas mentioned as follows:

$$\text{Microbial quotient } (\mu g \text{ of biomass C } \mu g \text{ TOC}^{-1}) = \frac{\text{Microbial biomass carbon (MBC)}}{\text{Total organic carbon}}$$

$$\text{Mineralisation quotient } (\mu g \text{ of biomass C } \mu g \text{ TOC}^{-1}) = \frac{\text{Cumulative CO}_2\text{-evolved in 32days}}{\text{Total organic carbon}}$$

2.4 Microbial biomass carbon

The estimation of microbial biomass carbon was done by chloroform fumigation method. The developed color intensity was measured at 570 nm wavelength in spectrophotometer (T70 UV/VIS Spectrometer) as demonstrated by Carter (1991) [6]. Absorbance values were compared with a standard curve and the microbial biomass C was calculated using the formula.

$$\text{Microbial Biomass C mg kg-1} = \frac{\text{Ninhydrin reactive-Nin fumigated soil-Ninhydrin reactive-N in unfumigated soil}}{\text{Weight of the soil sample}} \times 25$$

3. Results and Discussion

3.1Effect of long term application of organic manure and fertilizers on soil mineralizable carbon

Carbon mineralization rate varied significantly among the different treatments from the initial day of incubation experiment. Cumulative mineralization of carbon in different treatments is represented in the Table 2 and Fig. 1.

Carbon mineralization was significantly higher in the treatments that received farm yard manure along with inorganic fertilizers. The rate of carbon mineralization was recorded significantly higher in 100% NPK + FYM + lime (T_8: 820 µg $g^{-1}$of soil) which was on par with the plot treated with FYM + 100% NPK (T_7: 802 µg $g^{-1}$of soil). Application of super optimal dose of inorganic fertilizer (T_6: 150% NPK) has markedly increased cumulative carbon mineralization over 32 days of incubation period compared with the treatment received sub optimal dose (T_4: 50% NPK) of fertilizer. The carbon mineralized from T_6 and T_4 throughout the incubation period was 710 µg g^{-1} of soil and 414 µg $g^{-1}$of soil, respectively. Significantly lesser carbon mineralization was noticed in an absolute control treatment (T_1: 250 µg $g^{-1}$of soil) and it was on par with the treatment received only 100% N (T_2: 282 µg $g^{-1}$of soil). Carbon mineralization in the uncultivated soil did not record any higher values when compared with the FYM treated plots.

The SOC mineralization was faster at the beginning of the incubation study, which progressively decreased with the increase in time. The decrease in decomposition rate over time is probably due to rising concentrations of structural carbohydrates (such as lignin and hemicelluloses) as a result of the loss of other constituents (sugars and starches) in the detritus (Mcfilinge *et al.*, 2002) [21]. The treatment, 100% NPK + FYM+ lime showed greatest cumulative carbon mineralization throughout the incubation period, while the lowest mineralization was observed in control. Higher mineralization potential observed under NPK compared to imbalanced fertilizer application (100% NP and 100% N alone) can be attributed to the long term extraneous application of balanced fertilizer (100% NPK) that could prevent the depletion of soil nutrients and at the same time maintained higher level of organic carbon through recycling of root biomass which facilitated the growth of microbes. Rudrappa *et al.* (2006) [27] reported that, the differences in the rates of C mineralization are indicative of the variable amounts of labile organic C accumulated in different fertilizer treatment.

Table 2: Effect of long term manuring and fertilization on cumulative carbon mineralization (µg g^{-1}) in soil under finger millet-maize cropping system

Treatment	1st day	2nd day	3rd day	4th day	5th day	7th day	9th day	11th day	14th day	17th day	20th day	23rd day	26th day	29th day	32nd day
T_1: Control	9	21	38.00	63.00	96.00	141.00	172.00	182.00	195.00	202.00	214.00	222.00	228.00	237.00	250.00
T_2: 100% N	7	20	35.00	60.00	91.00	151.00	192.00	208.00	218.00	226.00	236.00	244.00	252.00	264.00	282.00
T_3: 100% NP	10	29	52.00	80.00	113.00	179.00	226.00	243.00	261.00	271.00	285.00	295.00	304.00	317.00	334.00
T_4: 50% NPK	17	43	83.00	113.00	139.00	217.00	269.00	289.00	310.00	324.00	340.00	354.00	375.00	391.00	414.00
T_5: 100% NPK	26	66	104.00	140.00	186.00	263.00	333.00	371.00	399.00	422.00	446.00	467.00	486.00	505.00	534.00
T_6: 150% NPK	39	84	135.00	200.00	264.00	352.00	423.00	466.00	509.00	555.00	599.00	627.00	653.00	679.00	710.00
T_7: 100% NPK+FYM	41	87	139.00	217.00	304.00	401.00	480.00	529.00	590.00	641.00	686.00	716.00	742.00	772.00	802.00
T_8:100%NPK+FYM+lime	48	97	151.00	237.00	321.00	415.00	495.00	550.00	611.00	666.00	701.00	735.00	758.67	788.00	820.00
T_9: Uncultivated soil	17	42	71.00	101.00	133.00	200.00	252.00	277.00	304.00	322.00	341.00	358.00	368.00	385.00	415.00
SEm±	2.43	4.51	5.90	5.41	8.16	8.26	8.37	8.90	8.40	8.53	10.04	10.76	11.41	12.22	12.74
CD @ 5%	7.28	13.52	17.69	16.22	24.46	24.78	25.10	26.69	25.18	25.57	30.10	32.25	34.20	36.64	38.21

Microbial activity, total organic C and several other physical and chemical parameters determine the mineralization potential of soil. Studies on long term fertilizer experiment showed integrated application of chemical fertilizer and organic manures apart from creating favorable environment for growth and activity of microorganisms also provided substrates for the mineralization processes. Similar results were also reported by Chen *et al.* (2008) [8]. The lowest value in the unfertilized control plot seems to be related to the unfavorable environment in the control arising out of the depletion of nutrients due to continuous cropping without any fertilization. This results in the depletion of nutrients and negatively affects the physical, chemical and biological parameters of soil thus creates an unfavourable environment for the microbial activity.

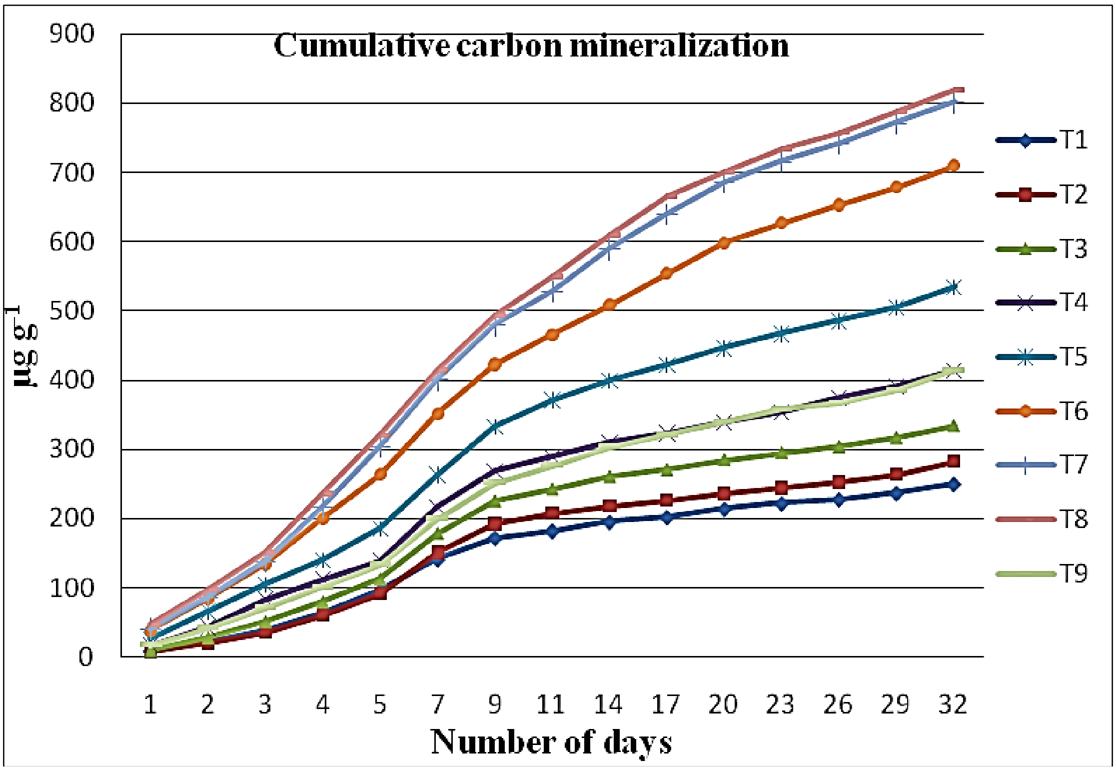

Fig1: Effect of long term manuring and fertilization on cumulative carbon mineralization (µg g^{-1}) in soil under finger millet-maize cropping system

3.2 Effect of long term application of organic manure and fertilizers on basal soil respiration

Basal soil respiration varied significantly among the different treatments during the incubation study. The results obtained are presented in the Table 3, Table 4 and Fig. 2.

Irrespective of treatments, the CO_2 evolution showed four distinct phases (Fig. 2). At the first phase CO_2 evolution showed an increasing trend and it reached the maximum at 5th day of incubation, the average CO_2 evolution at this phase ranges from 0.783 to 2.675 µg CO_2-C g^{-1} hr^{-1}. During the second phase (6th-11th day of incubation) there was a decreasing trend in the CO_2 evolution and it varied from 0.813 to 1.240 µg CO_2-C g^{-1} hr^{-1}. Highest CO_2 evolution at all the phases was noticed in the treatment received 100% NPK + FYM + lime and it was lowest in control. Again at the third phase (11th-14thday), CO_2 evolution increased, but the difference between the treatments was lesser compared with the first phase. After 14th day of incubation study, the CO_2 evolution showed decreasing trend and reached almost constant in the fourth phase. At the third and fourth phase the average amount of CO_2 evolved varied from 0.302 to 1.724 µg CO_2-C g^{-1} hr^{-1} and 0.127 to 0.491 µg CO_2-C g^{-1} hr^{-1}, respectively. The rate of CO_2 evolution was not same throughout the decomposition period as it is affected by different biotic and abiotic factors, the fluctuation in CO_2 evolution from decomposing organic materials were observed by Agbim *et al*. (1997) [1].

The availability of easily decomposable organic matter and readily available nutrients provided conducive environment for microbial activity, resulting in higher rate of respiration during the initial phase of the experiment. Kadalli *et al*. (2006) [14] also reported that labile fractions and easily degradable components availability for microorganisms is responsible for higher CO_2 evolution and in the later phases there will be accumulation of resistant carbon leads to low rate of CO_2 evolution and thus the biochemical decomposition narrow down. During the third phase again slight increase in CO_2 evolution due to decomposition of carbon from the dead microorganisms, which is easily accessible for microbial activity. At the fourth phase, there will be only resistant form of carbon present in the soil, which is not easily available for microbial activity and hence the CO_2 evolution reached almost constant.

Table 3: Average rate of soil respiration (µg CO_2-C g^{-1} hr^{-1}) in four phases of different treatments during the incubation period

Treatment	I Phase	II Phase	III Phase	IV Phase
T_1: Control	0.783	0.813	0.327	0.127
T_2: 100% N	0.759	1.052	0.302	0.148
T_3: 100% NP	0.942	1.177	0.468	0.169
T_4: 50% NPK	1.242	1.250	0.652	0.241
T_5: 100% NPK	1.550	1.531	0.888	0.313
T_6: 150% NPK	2.200	1.656	1.243	0.465
T_7: 100% NPK+FYM	2.533	1.834	1.662	0.491
T_8:100% NPK+FYM+lime	2.675	1.813	1.724	0.484
T_9: Uncultivated soil	1.108	1.240	0.779	0.257
SEm$\pm$	0.041	0.034	0.025	0.008
CD @ 5%	0.122	0.103	0.074	0.025

The different treatments had a significant impact on basal soil respiration. Basal soil respiration over 32 days of incubation period recorded significantly higher value of 0.444 µg CO_2-C g^{-1} hr^{-1} in the treatment that received FYM and lime along with 100% NPK (T_8) which was on par with the treatment received 150% NPK (T_6: 0.431 µg CO_2-C g^{-1} hr^{-1}) and the plot treated with FYM along with 100% NPK (T_7: 0.417 µg CO_2-C g^{-1} hr^{-1}). The BSR was highest under integrated application of fertilizer and FYM, and was higher than untreated control. Similar results were reported by Majumder *et al*. (2008) [20]. The availability of easily decomposable organic matter and readily available nutrients provided conducive environment for microbial activity, resulting in higher rate of respiration (Sayre *et al*., 2005) [28].

Basal soil respiration was significantly maintained lower values throughout 32 days of incubation period in an absolute control treatment (T_1: 0.181 µg CO_2-C g^{-1} hr^{-1}) which was on par with the treatment T_2 (100% N: 0.250 µg CO_2-C g^{-1} hr^{-1}) followed by the treatment received 100% NP (T_3: 0.236 µg CO_2-C g^{-1} hr^{-1}). Application of suboptimal dose (50% NPK) of fertilizer has recorded lower basal respiration values (T_4: 0.319 µg CO_2-C g^{-1} hr^{-1}) compared to the treatments with optimal dose of 100% NPK fertilizer (T_5: 0.403 µg CO_2-C g^{-1} hr^{-1}). Basal soil respiration in the uncultivated soil was lower (T_9: 0.417 µg CO_2-C g^{-1} hr^{-1}) when compared to the treatments with 100 per cent of inorganic fertilizer and FYM in combination.

Table 4: Effect of long term manuring and fertilization on basal soil respiration (µg CO_2-C g^{-1} hr^{-1}) in soil under finger millet-maize cropping system

Treatment	1st day	2nd day	3rd day	4th day	5th day	7th day	9th day	11th day	14th day	17th day	20th day	23rd day	26th day	29th day	32nd day
T_1: Control	0.375	0.500	0.708	1.042	1.292	0.979	0.646	0.208	0.445	0.097	0.167	0.111	0.083	0.125	0.181
T_2: 100% N	0.292	0.542	0.625	1.042	1.292	1.250	0.854	0.333	0.271	0.111	0.139	0.111	0.111	0.167	0.250
T_3: 100% NP	0.417	0.792	0.917	1.208	1.375	1.375	0.979	0.354	0.581	0.139	0.194	0.139	0.125	0.181	0.236
T_4: 50% NPK	0.708	1.083	1.667	1.250	1.500	1.417	1.083	0.417	0.887	0.194	0.222	0.194	0.292	0.222	0.319
T_5: 100% NPK	1.083	1.667	1.583	1.500	1.917	1.604	1.458	0.792	0.984	0.319	0.333	0.292	0.264	0.264	0.403
T_6: 150% NPK	1.625	1.875	2.125	2.708	2.667	1.833	1.479	0.896	1.589	0.639	0.611	0.389	0.361	0.361	0.431
T_7: 100% NPK+FYM	1.708	1.917	2.167	3.250	3.625	2.021	1.646	1.021	2.302	0.708	0.625	0.417	0.361	0.417	0.417
T_8:100% NPK+FYM+lime	2.000	2.042	2.250	3.583	3.500	1.958	1.667	1.146	2.302	0.764	0.486	0.472	0.333	0.403	0.444
T_9: Uncultivated soil	0.708	1.042	1.208	1.250	1.333	1.396	1.083	0.521	1.036	0.250	0.264	0.236	0.139	0.236	0.417
SEm$\pm$	0.101	0.128	0.138	0.180	0.149	0.076	0.072	0.055	0.507	0.036	0.032	0.029	0.029	0.030	0.036
CD @ 5%	0.303	0.384	0.414	0.538	0.447	0.229	0.217	0.165	1.521	0.107	0.097	0.087	0.087	0.091	0.109

The BSR reflects the catabolic degradation of soil microbial communities under aerobic conditions. It decreased in the order of 100% NPK+FYM >150% NPK >100% NPK >100% N >untreated control. Treatments had statistically similar values of BSR (Chakraborty *et al*., 2011) [7]. The lower value of qCO_2 and BSR to C_{mic}ratio in soils with balanced fertilization and C supplementation have been reported by many (Goyal *et al*., 1993; Lupwayi *et al*., 1998) [12, 16]. High value of qCO_2 and BSR to C_{mic}ratio for fallow are indicative of the presence of readily mineralizable C that has not yet led to growth of the microflora (Franzluebbers *et al.*, 1999) [11]. The increase of qCO_2 was also reflected in an increase in the ratio of active: dormant components of the microbial population.

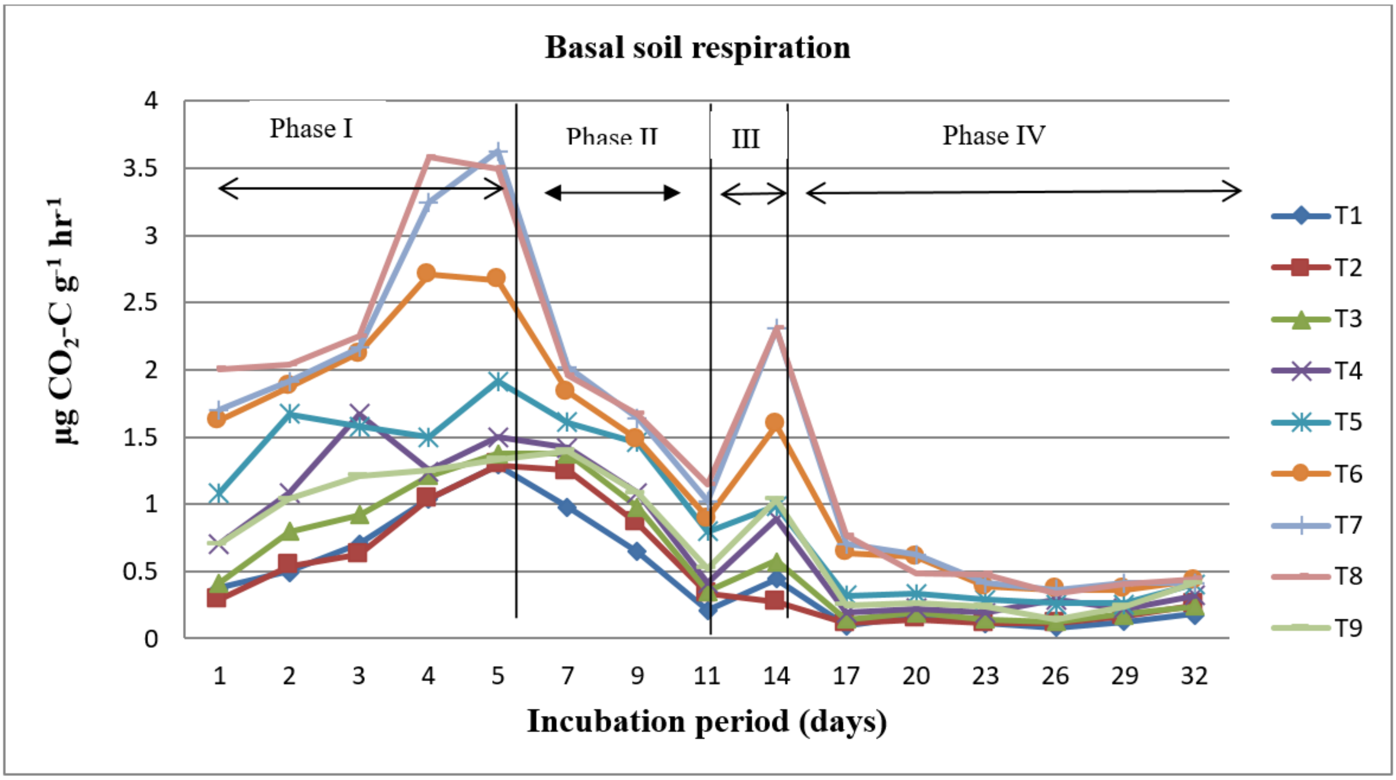

Fig 2: Effect of long term manuring and fertilization on basal soil respiration (µg CO_2-C g^{-1} hr^{-1}) in soil under finger millet-maize cropping system

3.3 Effect of long term application of organic manure and fertilizers on soil microbial indices

Microbial indices in the soil treated with continuous application of manures and fertilizers after 33 years of cropping sequence under finger millet-maize cropping system varied significantly among the different treatments. The results obtained are presented in the Table 5.

The microbial quotients are important indicators to assess the long term impact of nutrient management practices on soil quality (Liu *et al.*, 2010) [19]. A high microbial quotient generally implies presence of easily available C pool that sustains a large microbial community (Nilsson *et al.*, 2005) [23].

Microbial quotient was significantly higher in the treatment T_5: 100% NPK (2.98 g of biomass C 100 g total organic C^{-1}) which was on par with the treatment that has received 50% NPK (T_4: 2.85g of biomass C 100 g total organic C^{-1}). Significantly lower microbial quotient was recorded in the treatments that has received FYM along with 100% NPK [T_7: 100% NPK + FYM (1.92 g of biomass C 100 g total organic C^{-1})] which was on par with T_8: 100% NPK + FYM + lime (2.36 g of biomass C g 100 total organic C^{-1}). Application of super optimal dose (T_6: 150% NPK) of fertilizer has lower microbial quotient of 2.80 g of biomass C 100 g total organic C^{-1} compared to the treatment that received optimal dose (T_5: 100% NPK) of inorganic fertilizer and suboptimal dose (50% NPK) of fertilizers with the values of 2.98 g of biomass C 100 g total organic C^{-1} and 2.85 g of biomass C 100 g total organic C^{-1}, respectively. Rudrappa *et al.* (2006) [27] reported that microbial metabolic quotient was significantly lower in 100 per cent NPK + FYM to make it the most efficient manuring practice to preserve organic carbon in soil. A low microbial quotient suggests a higher accumulation of resistant organic carbon pool. This suggests an accumulation of resistant pool of C in the treatment NPK + FYM. Balanced fertilization with NPK provided better nutrition to microbial population thus increased the quotient over sole N or NP particularly in surface soil.

Mineralization quotient was recorded significantly higher value in the treatment received super optimal dose of fertilizer [T_6: 150% NPK (7.63 g of biomass C 100 g total organic C^{-1})] followed by the treatment which received FYM along with 100% NPK (6.74 g of biomass C 100 g total organic C^{-1}). Mineralization quotient was significantly lower in uncultivated soil (T_9: 2.86 g of biomass C 100 g total organic C^{-1}) which was on par with absolute control treatment (T_1: 3.67 g of biomass C 100 g total organic C^{-1}) followed by the plot treated with imbalanced nutrient supply of 100% N (T_2: 3.75 g of biomass C 100 g total organic C^{-1}).

Table 5: Effect of long term manuring and fertilization on soil microbial indices under finger millet-maize cropping system

Treatment	Microbial quotient (g of biomass C 100 g total organic C^{-1})	Mineralization quotient (g CO_2-C 100 g^{-1} TOC)	Microbial biomass carbon (mg kg^{-1})	Basal soil respiration quotient (µg CO_2-C mg^{-1} TOC day^{-1})
T_1: Control	2.87	3.67	195.92	0.775
T_2: 100% N	2.72	3.75	205.18	0.966
T_3: 100% NP	2.70	4.13	216.97	0.838
T_4: 50% NPK	2.85	5.00	236.90	1.003
T_5: 100% NPK	2.98	6.18	257.95	1.156
T_6: 150% NPK	2.80	7.63	262.16	1.106
T_7: 100% NPK+FYM	1.92	5.99	258.51	0.695
T_8:100%NPK+FYM+lime	2.36	6.74	286.58	0.802
T_9: Uncultivated soil	2.23	2.86	324.76	0.688
SEm±	0.19	0.24	16.19	0.022
CD @ 5%	0.57	0.74	48.53	0.065

Higher mineralization quotient observed in the treatments with balanced application of chemical fertilizers suggests higher efficiency of utilization and conservation of organic matter under the particular nutrient management (Mocali *et al*., 2008) [22]. With the combined application of chemical fertilizer and organic manure, the immediate N requirement of plant was met from the chemical fertilizer; only a fraction of the organic N in manure is mineralized during the season of application, while the remainder decomposes slowly over many years (Endelman *et al*., 2010) [10].

Significantly higher microbial biomass carbon (MBC) content was found in uncultivated soil (T_9: 324. 76 mg kg^{-1}). Among the cultivated soils, microbial biomass carbon was high in the treatment which received 100% NPK + FYM + lime (T_8: 286.58 mg kg^{-1}) followed by the plot which received super optimal dose of inorganic fertilizer *i.e.*, 150% NPK (T_6: 262.16 g kg^{-1}). The integrated approach of nutrient management showed positive impact on soil microbial biomass carbon and received more biomass carbon. Microbial biomass carbon content was found significantly lower in absolute control (T_1: 195.92 mg kg^{-1}) which was on par with T_2: 100% N (205.18 mg kg^{-1}) and T_3: 100% NP (216.97 mg kg^{-1}). The lowest MBC concentration was obtained under control and highest with balanced fertilization of 100% NPK with FYM. The results were also in agreement with the findings of Pant *et al*. (2020) [25]. Low MBC in the control treatment is because of unfavorable environment arising out of depletion of nutrients due to continuous cropping without any fertilization.

The rate of CO_2 evolution was significantly higher in the treatment received 100% NPK (T_5:1.156 µg CO_2-C mg^{-1} TOC day^{-1}) which was on par with the treatment T_6 which received super optimal dose of fertilizer *i.e.*, 150% NPK (1.106 µg CO_2-C mg^{-1} TOC day^{-1}). Significantly lower CO_2 evolved per day was recorded in T_9: fallow land (0.688 µg CO_2-C mg^{-1} TOC day^{-1}) which was on par with the treatment received FYM along with 100% NPK (T_7: 0.695 µg CO_2-C mg^{-1} TOC day^{-1}).

5. Conclusion

The results showed significant variations in carbon mineralization due to long term fertilization and manuring practices; higher potentially mineralizable C was recorded under combined application of chemical fertilizers and FYM. Besides, higher values of microbial and mineralization quotients were also observed in balanced fertilizer treated plots. Moreover, three decades of manure application significantly improved the C mineralization potential for SOC. The turnover rate of mineralization for SOC is ascribed to higher microbial activities which are crucial for the breakdown of organic matter. Therefore, maintaining soil fertility depends on the biomass of microorganisms and the activity of extracellular enzymes, which are crucial in SOC mineralization potential. Future studies need to quantify net ecosystem C budget to understand the effect of long-term nutrient management practices on soil's feedback to atmospheric CO_2.

6. References

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