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# Changes in Labile Pools of Soil Organic Carbon in Relation with Crop Productivity in Different Long-term Fertilizer Treatments

**A. Krishna Chaitanya[1*], M. Suresh[2], Shyam Prasad Majumder[1] and Ch. Sreenivas[3]**

*[1]Bidhan Chandra Krishi Viswavidyalaya, Kalyani-741235, West Bengal, India.*
*[2]Professor Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, India.*
*[3]Acharya N. G. Ranga Agricultural University, Rajamahendravaram - 533 101, A.P., India.*

***Authors' contributions***

*This work was carried out in collaboration between all authors. Author AKC designed the study, performed the statistical analysis and wrote the manuscript. Authors MS and SPM managed the literature search and helped in manuscript writing. Author CS managed the field. All authors read and approved the final manuscript.*

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## ABSTRACT

Studying the dynamics of soil organic carbon (SOC) is important for understanding the carbon stabilization into different pools. Thus, a 25-year old experiment was used to assess the impact of double rice cropping system with addition of organics and grades of fertilization on labile carbon pools and crop yield sustainability in an Inceptisol in southern India. There was significant decrease ($p<0.05$) in bulk density with increase in the use of organics over control. Green manure applied (in combination with NPK or NPK+farmyard manure) showed greater mineralisable carbon hence, could say greater microbial activity and carbon turnover. The lowest value of microbial quotient (MQ) in the control indicated a poor quality soil with impairment of its capacity for C cycling. The better nutritional environment to microbial population in the soils under balanced fertilization along with organics increased the quotient. The higher respiration quotient ($qCO_2$) in the control treatment suggested a less efficient use of available carbon by the microbes there.

**Corresponding author: E-mail: krch3737@outlook.com;*

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## 1. INTRODUCTION

Soil organic carbon (SOC) is one of the most important components in soil that contributes positively to soil fertility, soil tilth, crop production, and overall soil sustainability [1,2]. Since soil is the major reservoir of terrestrial C any attempt to enrich this reservoir through sequestration of atmospheric C will help to manage global warming and achieve global food security to a great extent.

Assessing the labile pools might be a useful approach for the characterization of SOC resulting from different soil management practices including cropping systems and application of organic and inorganic sources of nutrients. Some of the most important labile pools of SOC currently used as indicators of soil quality are: microbial biomass carbon (MBC), mineralizable carbon (Cmin), oxidisable organic carbon (OC) fractions etc., and serves as a good indicator for the purpose.

Long-term experiments are useful to monitor the changes in pools of SOC as influenced by different cropping systems, soil management practices etc., since short-term experimentations may not have a discernible effect on such changes. Only a very few studies have so far been made considering almost all the important labile pools of SOC particularly in tropical and sub-tropical regions of the world [3]. In India, a series of long-term fertility experiments were initiated during late sixties and early seventies when fertilizer responsive high yielding varieties (HYV) crops were introduced with a view to ascertain their nutrient requirement and also maintenance of soil quality using both organic and inorganic sources of nutrients. Productivity analysis, nutrients balance and soil quality studies were conducted for some of these experiments [4,5,6]. In the present study, we examined the soils of long-term fertility experiment from southern India with the aims to examine the changes occurred in allocation of carbon pools under different organic and inorganic inputs.

## 2. MATERIALS AND METHODS

### 2.1 Site Description

A long-term experiment was established in the year 1989, at the experimental farm of the Andhra Pradesh Rice Research and Regional Agricultural Research Station, Maruteru, Andhra Pradesh (16.37$^{o}$N and 16.40$^{o}$N, and 81.44$^{o}$E and 81.46$^{o}$E and 8.2 m above mean sea level, Fig. 2.) with double rice (*Oryzasativa*L.). Crop was sown every year during *kharif* i.e. mid June to mid-October and *rabi* i.e. mid November to mid March. The area receives, on an average, annual rainfall of approximately 1200 mm. The mean annual minimum and maximum temperatures were 10.0$^{o}$C and 37.6$^{o}$C, respectively. The soil was classified as *inceptisol*, with clay loam texture developed from the deltaic sediments of Godavari River. The site had the soil moisture and temperature regimes of udic and mesic/thermic, respectively.

Two rice (*Oryzasativa*L.) crops (varieties: MTU-2067, 1061, 1010) were grown annually in the experiment. The experiment was laid out in randomized complete block design with three replications and consisted of the following treatments: (i) control (plots without NPK fertilizers and organics), (ii) 50% NPK (45:30:30), (iii) 50% NPK + 50% N- green manure (GM-*Calotropis*sps.), (iv) 50% NPK + 50% N- farmyard manure, (v) 50% NPK + 25% N- green manure (*Calotropis*sps.) + 25% N- farmyard manure, (vi) farmyard manure (10 t ha$^{-1}$), (vii) 100% NPK + farmyard manure (5 t ha$^{-1}$), (viii) 100% N and (ix) 100% NPK (90:60:60).

### 2.2 Soil Sampling

Three representative soil samples (0-15 cm) were collected randomly at the same time 7 days after rice harvest from each plot as the effects of inorganic and organic amendments on soils are typically restricted to this layer (Mandal et al. 2007). Field-moist soil samples were hand crushed and passed through a 2.0 mm sieve and stored at 4◦C. These fresh field-moist sieved samples were used for the estimation of soil microbial biomass carbon and mineralizable carbon. Air-dried soil samples that had passed through the same sieve were used for analysis of a selected suite of physico-chemical properties. In each plot, duplicate undisturbed soil core samples were taken by using a 50 mm diameter core sampler to determine bulk density (BD).

### 2.3 Soil Analysis

The pH of the soil was determined in 1: 2.5:: soil : water and soil : 0.02 M $CaCl_2$ suspension by using digital pH meter [7]. Electrical conductivity (EC) of soil-water suspension (1: 2.5) was estimated with the help of a direct reading conductivity meter (Model: systronics, 363) outlined by Jackson [7]. Bulk density was determined by core sampler (5.0 cm length and 5.0 cm diameter) method following the protocol of Blake and Hartge [8]. Soil organic carbon was determined by using rapid titration method (wet combustion method) as described by Walkley and Black [9].

### 2.4 Microbial Biomass Carbon (MBC)

Field-moist soil samples (25.0 g) were exposed to methyl chloride ($CHCl_3$)vapour for 24 h and extracted with 0.5 *M* $K_2SO_4$. A second non-fumigated set of samples was also extracted under similar conditions. The difference between C obtained from the fumigated and from the non-fumigated ones was taken to represent the microbial C-flush and converted to microbial biomass carbon (MBC) using the relationship: MBC = 1/0.41 $\times$ C-flush [10]. Microbial quotient was calculated as the ratio of MBC to total organic carbon (TOC). Respiratory quotient or metabolic quotient ($qCO_2$) was measured as the ratio of $C_{min}$ to MBC and expressed as g $CO_2$ evolved per d per g MBC.

### 2.5 Mineralizable Organic Carbon ($C_{min}$)

Fifty (50.0) gram of field-moist samples were wetted to 50.0% water-filled pore space, placed in a 1.0 *l* canning jar along with vials containing 10.0 ml of 0.5 *N*NaOH to trap evolved $CO_2$ and water to maintain humidity, and incubated for 23 d at 25 ± $2^0$C. Alkali traps were replaced at 3, 6 and 13 d and finally removed at 23 d. Evolved $CO_2$ was calculated by titrating the alkali in the traps with 1.0 *N*HCl to a phenolphthalein endpoint [11]. Basal soil respiration (BSR), an estimate of potential microbial activity, was calculated as the linear rate of respiration during 10 to 23 d incubation. The total amount of $CO_2$-C evolved during the 23 d incubation ($C_{min-23d}$) was taken as a measure of the potential mineralizable C of the soil [12].

### 2.6 Carbon Input to the Soil from Crop Residue and Organics

Empirical equations were used to estimate crop residue-derived C inputs. Stubble biomass and rhizodeposition C of rice, was assumed to be 2.5 and 15% of total above ground biomass at maturity and root biomass assumed as 19 and 14% of total above ground biomass for control and other fertilized treatments, respectively [13]. The extra C input through photosynthetic aquatic organism of rice was also accounted for following Saito and Watanabe [14]. The estimated C concentrations of rice stubbles and root residues were 31.8 and 41.2%, while mean C concentrations of FYM and GM were 26.35 and 32.36%, respectively.

### 2.7 Experimental Design and Statistical Analysis

Statistical analysis was performed by Windows-based SPSS program (ver. 17.0). The SPSS procedure was used for the analysis of variance (ANOVA) to determine the statistical significance of treatment effects. Duncan's Multiple Range Test (DMRT) was used to compare the treatment means. Simple correlation coefficients equations were also developed to evaluate relationships between the response variables using the same statistical package. The 5% probability level was regarded as statistically significant.

## 3. RESULTS AND DISCUSSION

### 3.1 Soil Physico-chemical Properties

Changes in basic physico-chemical properties of the soils under different treatments are presented in Table 1. The soils were acidic to neutral in reaction with $pH_w$ and $pH_{Ca}$ ranging from 6.26 to 6.97 and 5.57 to 6.21, respectively. The lowest $pH_w$ (6.26) under NPK+FYM treatment and $pH_{Ca}$ (5.57) under control treatment were observed. However, highest $pH_w$ and $pH_{Ca}$ (6.97 and 6.21, respectively) were observed in NPK treatment. The pH of the soils was lower in all the treatments when measured in 0.01M $CaCl_2$ solution ($pH_{Ca}$). On an average, $pH_{Ca}$ was about 0.67 units less than that of the $pH_w$ irrespective of treatments.

The bulk density values of the soils under different treatments varied from 1.20 to 1.33 Mg $m^{-3}$ (Table 1). The 50% NPK+GM+FYM treatment had the lowest bulk density value at i.e. 1.20 Mg $m^{-3}$. Soil bulk density has inverse relation with application of organic matter from green manure and/or farmyard manure. Soil BD decreased with the application of organics because of increase in SOC concentration and the root biomass [15]. The attendant increase in aggregation and macroporosity improved soil tilth and aeration, with the application of organic matter could be the reason for decreased bulk density [16]. Soil BD was negatively correlated with TOC concentration (Y = -48.54x + 81.44, $R^2$ = 0.89).

The oxidizable organic C content of the soils varied from 10.1 to 14.5 g $kg^{-1}$ among the treatments; on an average, its magnitude had the following orders: NPK+FYM (14.5 g $kg^{-1}$) > 50% NPK+FYM (13.5 g $kg^{-1}$) > 50% NPK+GM (13.2 g $kg^{-1}$) > FYM = NPK (12.8 g $kg^{-1}$) > 50% NPK+GM+FYM (12.1 g $kg^{-1}$) > 50% NPK (11.4 g $kg^{-1}$) > N (11.0 g $kg^{-1}$) > control (10.1 g $kg^{-1}$) treatments (Table 1).

## 3.2 Yield and Plant Derived C Inputs Into Soil

On average, grain yield was higher for both seasons (*kharif* and *rabi*) with NPK along with FYM than only NPK or other treatments (Fig. 2). Crop residues left over in the fields were computed from the existing database in literature taking into consideration the data of biomass yield obtained during the whole period of experimentation (Table 5). The cumulative C input values for the studied cropping systems were computed using harvested yield data for the last 25 years (1989–2014). Following the procedure as stated in material methods above, an estimate of plant derived C inputs into the soils was made (Table 2).

Results from the yield data showed that the yields were significantly ($p < 0.05$) increased with the application of different inorganic, organic inputs as compared to control. The annual C input value was significantly ($p< 0.05$) higher in RDF+FYM treatment (3.67 Mg $ha^{-1}$) as compared to the others. Balanced fertilization with organics has improved crop biomass and yields, subsequently contributed greater amount of C incorporated into the soils. This was supported by the existence of a significant positive correlation between them ($R^2$=0.89; $P \le 0.01$). Similar relationship between crop yield and associated annual C inputs into soils have also been reported by others [15, 5 and 17]. Cultivation with or without inorganics (RDF and control) produced 1.16 and 2.12 fold lower annual C inputs, respectively than RDF+FYM treatment (Table 2).

**Table 1. Some basic physico-chemical properties of experimental soils**

| | pHw | pHca | BD | OC | TOC |
|---|---|---|---|---|---|
| Control | $6.27^{b}$ | $5.57^{b}$ | $1.33^{a}$ | $10.1^{d}$ | $16.9^{c}$ |
| 50% NPK | $6.56^{ab}$ | $5.83^{ab}$ | $1.30^{ab}$ | $11.4^{cd}$ | $18.6^{bc}$ |
| 50% NPK+GM | $6.55^{ab}$ | $5.94^{ab}$ | $1.25^{bc}$ | $13.2^{ab}$ | $20.1^{ab}$ |
| 50% NPK+FYM | $6.60^{ab}$ | $5.85^{ab}$ | $1.25^{bc}$ | $13.5^{ab}$ | $21.4^{ab}$ |
| 50% NPK+GM+FYM | $6.43^{b}$ | $5.81^{ab}$ | $1.20^{c}$ | $12.1^{bc}$ | $22.4^{a}$ |
| FYM | $6.39^{b}$ | $5.76^{ab}$ | $1.27^{abc}$ | $12.8^{b}$ | $19.8^{abc}$ |
| NPK+FYM | $6.26^{b}$ | $5.68^{b}$ | $1.24^{bc}$ | $14.5^{a}$ | $22.1^{a}$ |
| N | $6.28^{b}$ | $5.68^{b}$ | $1.28^{ab}$ | $11.0^{cdc}$ | $18.6^{bc}$ |
| NPK | $6.97^{a}$ | $6.21^{a}$ | $1.27^{abc}$ | $12.8^{b}$ | $20.5^{ab}$ |

*$pH_w$-pH measured in distilled water, $pH_{ca}$- pH measured in 0.01M $CaCl_2$ solution, BD- Bulk Density, OC- Oxidizable Organic Carbon, TOC- Total Organic Carbon*

**Table 2. Annual C inputs (Mg $ha^{-1}$) returned to soil from rice-rice cropping system**

| | BC stub | BC root | C rhiz | BC aqua | Organic amended C | Annual C input |
|---|---|---|---|---|---|---|
| Control | 0.09 | 0.84 | 0.66 | 0.14 | | 1.73 |
| 50% NPK | 0.14 | 1.33 | 1.05 | 0.14 | | 2.67 |
| 50% NPK+GM | 0.16 | 1.51 | 1.19 | 0.14 | 0.28 | 3.28 |
| 50% NPK+FYM | 0.16 | 1.54 | 1.22 | 0.14 | 0.34 | 3.39 |
| 50% NPK+GM+FYM | 0.16 | 1.52 | 1.20 | 0.14 | 0.31 | 3.34 |
| FYM | 0.14 | 1.33 | 1.05 | 0.14 | 0.84 | 3.50 |
| NPK+FYM | 0.17 | 1.64 | 1.30 | 0.14 | 0.42 | 3.67 |
| N | 0.14 | 1.31 | 1.04 | 0.14 | | 2.62 |
| NPK | 0.17 | 1.60 | 1.26 | 0.14 | | 3.16 |

*BC Stub-Biomass carbon from stubbles, BC Root- Biomass carbon from roots, C Rhiz- carbon from rhizo exudates, BC Aqua- Biomass carbon from Aquatic organisms*

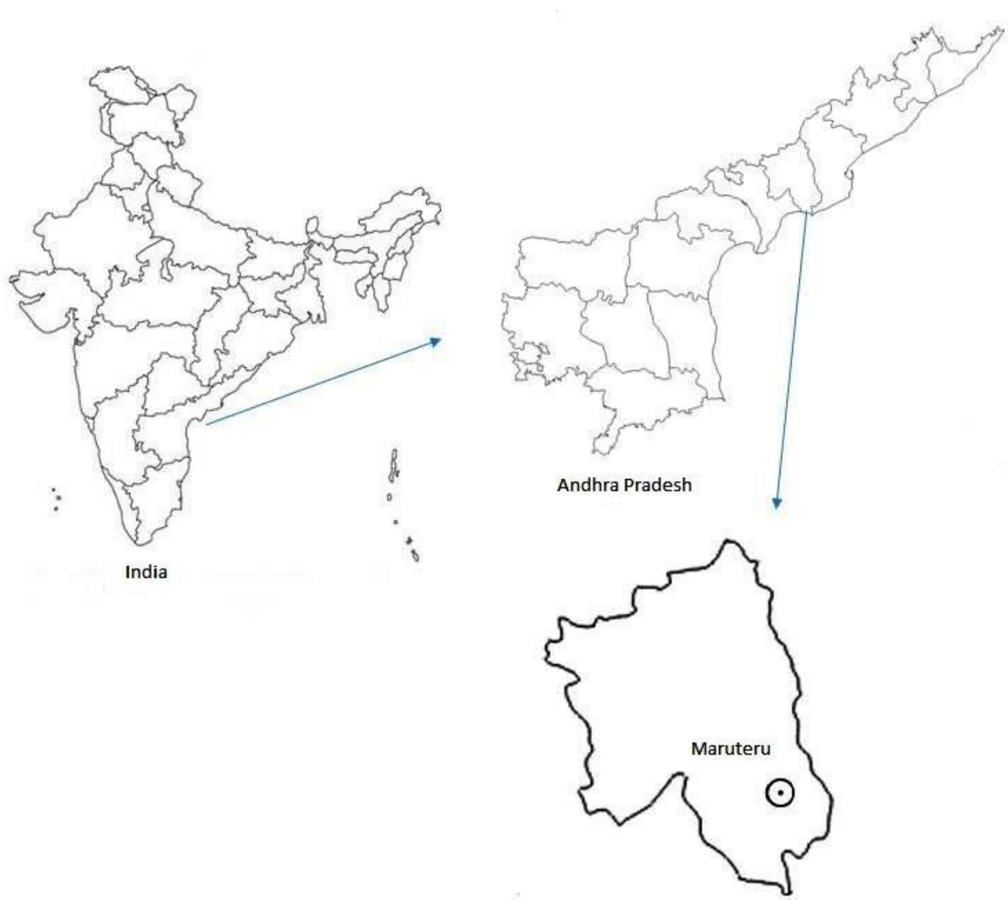


**Fig. 1. Map showing the study area**

### 3.3 Mineralizable C and Soil Respiration

On an average, mineralizable carbon content varied from 0.68 to 1.34 with a mean value of 1.05 g C kg$^{-1}$ soil, constituting about 5.19% of the TOC (Table 3); the amount under different treatments followed the order: 50% NPK+FYM+GM > 50% NPK+GM > NPK+FYM > FYM > 50% NPK+FYM > NPK > NP > N > control. Such higher amount observed within a short span of 23 days is, however, typical in soils of tropical and subtropical regions, where the organic matter turnover rates have been reported to be higher [3,5]. A higher proportion in 50%NPK+FYM+GM (6.0%) treatment (Table 5) over others indicated a higher activity of microorganisms in soils. The basal soil respiration (BSR) also followed a similar trend (Table 4). Interestingly, its value in the 50% NPK+GM was almost equal to that in the FYM treatment. The microbial biomass carbon (MBC) content under different treatments varied from 0.14 to 0.35 with a mean value of 0.27 g C kg$^{-1}$ soil (Table 4), and was in the following order: control < N < 50% NPK < NPK < 50%NPK+GM < 50%NPK+FYM < 50% NPK+FYM+GM < FYM< NPK+FYM. The microbial quotient (MQ, MBC as a proportion of TOC) ranged from 0.008 to 0.018 with a mean value of 0.013 (Table 4). The respiratory quotient ($qCO_2$) or metabolic quotient (the ratio of Cmin and MBC) was, however, significantly higher under the control over FYM treatment while other treatments were on par (Table 4). The rate of C mineralization and basal soil respiration (Cmin-10-24d, BSR) represent the performance of soil organic C decomposers. Higher rate of $CO_2$ production in the FYM and 50% NPK+GM indicated high rates of organic matter turnover in soils. The higher rates C mineralization during the initial 0 to 3 or 3 to 10 d period may be due to the disturbance of the soil during sampling, sieving and processing, which resulted in greater availability of metabolically accessible compounds [18].

**Table 3. Influence of treatments on distribution of mineralizable C in soils**

| | Cmin-0-3 d (g C $kg^{-1}$ $day^{-1}$) | Cmin-3-6 d (g C $kg^{-1}$ $day^{-1}$) | Cmin-6-13 d (g C $kg^{-1}$ $day^{-1}$) | Cmin-13-23 d (g C $kg^{-1}$ $day^{-1}$) | Cmin-0-23 d (g C $kg^{-1}$) |
|---|---|---|---|---|---|
| Control | 0.040$^{b}$ | 0.036$^{c}$ | 0.027$^{d}$ | 0.026$^{c}$ | 0.682$^{e}$ |
| 50% NPK | 0.046$^{b}$ | 0.042$^{c}$ | 0.038$^{cd}$ | 0.033$^{ab}$ | 0.864$^{d}$ |
| 50% NPK+GM | 0.082$^{a}$ | 0.078$^{a}$ | 0.056$^{ab}$ | 0.042$^{bc}$ | 1.293$^{ab}$ |
| 50% NPK+FYM | 0.072$^{a}$ | 0.062$^{ab}$ | 0.046$^{bc}$ | 0.041$^{ab}$ | 1.135$^{bc}$ |
| 50% NPK+GM+FYM | 0.077$^{a}$ | 0.073$^{a}$ | 0.061$^{a}$ | 0.046$^{a}$ | 1.336$^{a}$ |
| FYM | 0.068$^{a}$ | 0.062$^{ab}$ | 0.050$^{abc}$ | 0.041$^{ab}$ | 1.145$^{bc}$ |
| NPK+FYM | 0.076$^{a}$ | 0.064$^{ab}$ | 0.051$^{abc}$ | 0.041$^{ab}$ | 1.193$^{ab}$ |
| N | 0.041$^{b}$ | 0.041$^{c}$ | 0.031$^{d}$ | 0.031$^{c}$ | 0.771$^{de}$ |
| NPK | 0.051$^{b}$ | 0.047$^{bc}$ | 0.047$^{bc}$ | 0.041$^{ab}$ | 1.026$^{c}$ |

*Cmin- carbon mineralised, d- day*

**Table 4. Influence of treatments on distribution of microbial biomass C (MBC), microbial quotient (MQ) and basal soil respiration (BSR) in soils**

| | MBC (g $kg^{-1}$) | MQ | $qCO_2$ (g $CO_2$–$Cg^{-1}$Cmic $day^{-1}$) | BSR ($CO_2$-C $Kg^{-1}$ $day^{-1}$) |
|---|---|---|---|---|
| Control | 0.142$^{e}$ | 0.008$^{e}$ | 0.216$^{a}$ | 0.156$^{b}$ |
| 50% NPK | 0.220$^{d}$ | 0.011$^{cde}$ | 0.175$^{ab}$ | 0.177$^{ab}$ |
| 50% NPK+GM | 0.286$^{bc}$ | 0.014$^{abcd}$ | 0.201$^{ab}$ | 0.211$^{a}$ |
| 50% NPK+FYM | 0.313$^{ab}$ | 0.015$^{abcd}$ | 0.159$^{ab}$ | 0.191$^{ab}$ |
| 50% NPK+GM+FYM | 0.337$^{ab}$ | 0.015$^{abc}$ | 0.173$^{ab}$ | 0.207$^{ab}$ |
| FYM | 0.348$^{a}$ | 0.018$^{a}$ | 0.144$^{b}$ | 0.212$^{a}$ |
| NPK+FYM | 0.350$^{a}$ | 0.016$^{ab}$ | 0.149$^{ab}$ | 0.187$^{ab}$ |
| N | 0.194$^{de}$ | 0.010$^{de}$ | 0.175$^{ab}$ | 0.165$^{ab}$ |
| NPK | 0.247$^{cd}$ | 0.012$^{bcde}$ | 0.189$^{ab}$ | 0.199$^{ab}$ |

*MBC-microbial biomass carbon, MQ - microbial quotient, $qCO_2$ – respiration quotient, BSR- basal soil respiration*

**Table 5. Correlation coefficients (r) among different soil organic C pools and with crop productivity**

| | pHw | pHca | BD | OC | TOC | Cmin | MBC | MQ | $qCO_2$ | BSR | ACI | Yield |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| pHw | 1 | | | | | | | | | | | |
| pHca | .96$^{**}$ | 1 | | | | | | | | | | |
| BD | -.09 | -.26 | 1 | | | | | | | | | |
| OC | .29 | .39 | -.63 | 1 | | | | | | | | |
| TOC | .20 | .34 | -.94$^{**}$ | .79$^{*}$ | 1 | | | | | | | |
| Cmin | .19 | .36 | -.90$^{**}$ | .66 | .87$^{**}$ | 1 | | | | | | |
| MBC | .04 | .18 | -.82$^{**}$ | .61 | .87$^{**}$ | .90$^{**}$ | 1 | | | | | |
| MQ | .02 | .15 | -.71$^{*}$ | .50 | .76$^{*}$ | .84$^{**}$ | .98$^{**}$ | 1 | | | | |
| qCO2 | .16 | .1 | .49 | -.32 | -.57 | -.41 | -.75$^{*}$ | -.77$^{*}$ | 1 | | | |
| BSR | .41 | .57 | -.71$^{*}$ | .43 | .69$^{*}$ | .90$^{**}$ | .81$^{**}$ | .82$^{**}$ | -.36 | 1 | | |
| ACI | .23 | .39 | -.81$^{**}$ | .73$^{*}$ | .88$^{**}$ | .87$^{**}$ | .95$^{**}$ | .92$^{**}$ | -.73$^{*}$ | .82$^{**}$ | 1 | |
| Yield | .48 | .62 | -.79$^{*}$ | .84$^{**}$ | .87$^{**}$ | .76$^{*}$ | .73$^{*}$ | .64 | -.51 | .68$^{*}$ | .89$^{**}$ | 1 |

### 3.4 Microbial Biomass C, Microbial Quotient and Respiratory Quotient

The microbial biomass C, which normally constitutes about 1–5% of the TOC, can provide an early warning for a possible degrading and/or aggrading effect of different management practices on soil quality [4]. The lower value of MBC in the control treatment (Table 4) seemed to be related to its unfavourable environment arising from depletion of nutrients due to continuous cropping without any treatment (Table 4) was due to its congenial environment for microbial growth for C enrichment through plant residue incorporation as well as FYM application [19]. This observation is consistent with that of Hopkins and Shiel [20].

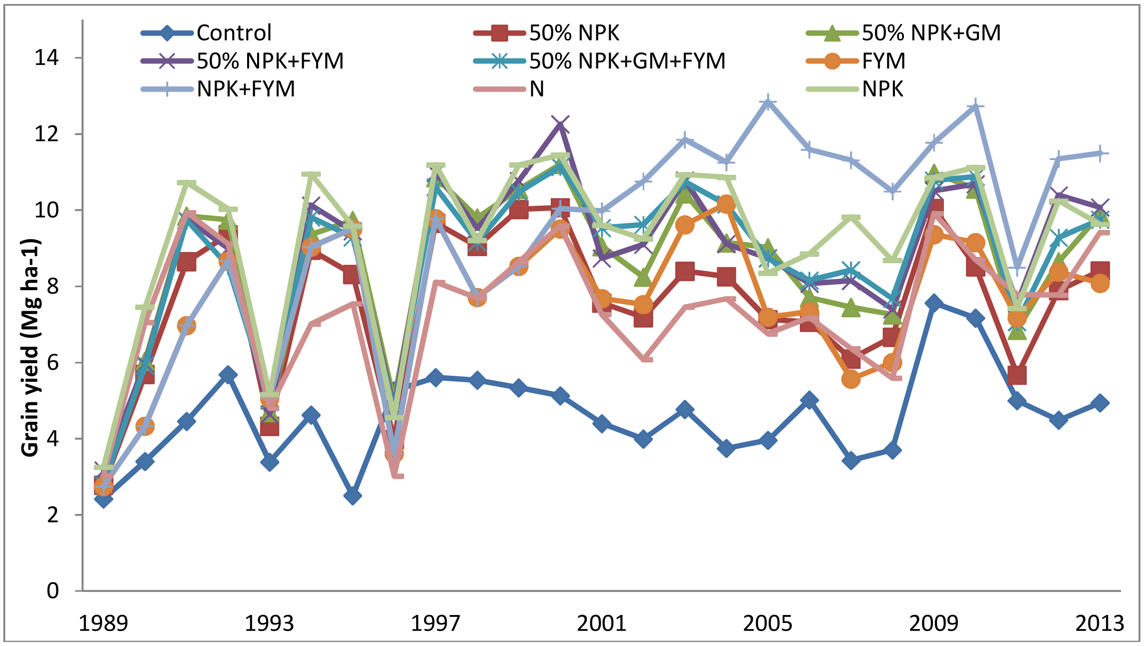


**Fig. 2. Annual grain yield (Mg ha-1) of rice under different treatments (1989-2014)**

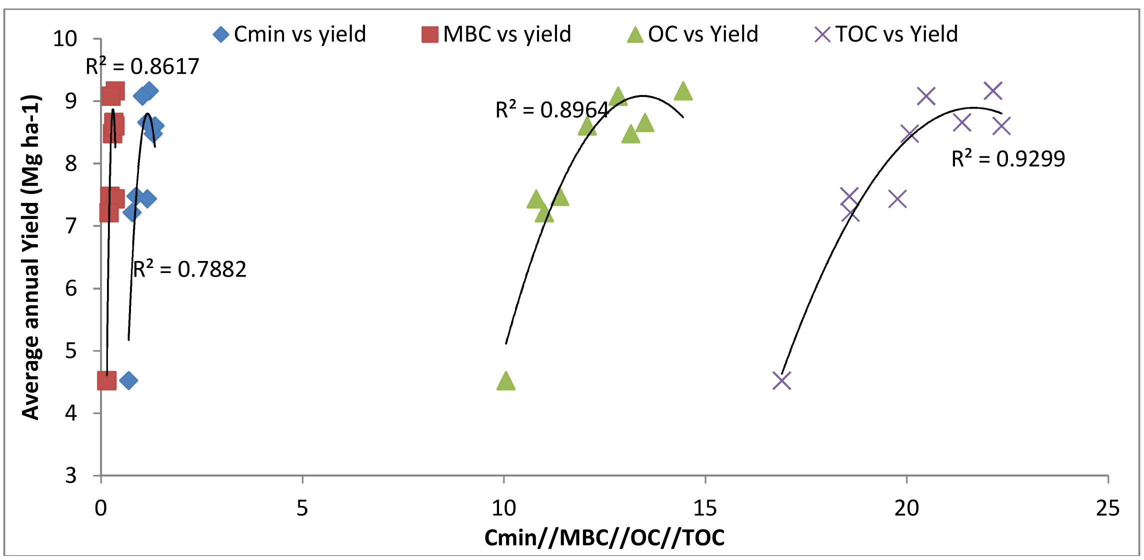


**Fig. 3. Relationship of oxidisable organic (OC), microbial biomass carbon (MBC), mineralizable C (Cmin) and total organic C (TOC) with the equivalent rice yield**

The values of MQ for the soils were within the range of 1 to 5% (Table 4). Its higher value with FYM suggested a greater stability of organic C under the treatment [21]. The lowest value of MQ in the unfertilized control indicated a poor quality soil with impairment of its capacity for C cycling [22]. The better nutritional environment to microbial population in the soils under balanced fertilization compared to control and sole N treatments increased the quotient [3]. The higher $qCO_2$ in the control and 50% NPK+GM treatments (Table 4) suggested a less efficient use of available C by the microbes there. Although $qCO_2$ undoubtedly indicates microbial efficiency, several factors such as, nature of residue C incorporated into the soil, soil moisture, qualitative changes within microbial population (e.g., increase in the proportion of fungi) etc. may also explain the differences in $qCO_2$ within the treatments. The higher metabolic efficiency (i.e., lower $qCO_2$) of microbial population in the fertilized treatments such as FYM and NPK+FYM as observed in the present study suggests that these treatments were most efficient in preserving C in soil.

The relationships between the yield with Cmin, MBC, OC and TOC were strong (Fig. 3). They accounted for as much as 79, 86, 90 and 93% variability in rice equivalent yield, respectively. This suggests the importance of these pools of SOC in influencing the yield of the crops through maintaining a better soil quality.

## 5. CONCLUSION

Balanced fertilization along with organics (NPK+FYM) could maintain good amount of soil OC, TOC and MBC. Annual carbon input was also greater in NPK+FYM, this could be the reason for greater amount of carbon pools. Green manure applied (in combination with NPK or NPK+FYM) showed greater mineralisable carbon hence, could say greater microbial activity and C turnover. The lowest value of MQ in the control indicated a poor quality soil with impairment of its capacity for C cycling. The better nutritional environment to microbial population in the soils under balanced fertilization along with organics increased the quotient. The higher $qCO_2$ in the control treatment suggested a less efficient use of available C by the microbes there.

## COMPETING INTERESTS

Authors have declared that no competing interests exist.

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