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Long term effect of inorganic fertilizers and organic manures on soil fertility status, microbial biomass carbon, and yield of rice on inceptisol

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Abstract

The experiment was conducted during the kharif season at research farm, Indira Gandhi Krishi Viswavidyalaya, Raipur to investigate the long term effect of Inorganic fertilizer and organic manures on soil fertility, microbial biomass carbon and yield of rice. The soil was sandy loam and locally known as matasi, neutral in pH, Low in nitrogen, medium in P and K. The experiment was laid in RBD and replicated three times with eleven treatments: T₁ -No Fertilizer, No Organic manure (Control), T₂ -50% Recommended NPK (40:30:20), T₃-75% Recommended NPK, T₄-100% Recommended NPK (80:60:40), T₅-50% Recommended NPK +50%N through Farm yard manure, T₆ -75% Recommended NPK +25%N through Farm yard manure, T₇-50% Recommended NPK +50%N through rice residue, T₈-75% Recommended NPK +25%N through rice residue, T₉-50% Recommended NPK +50%N through Green manure, T₁₀-75% Recommended NPK +25%N through Green manure, T₁₁. Conventional Farmer's Practice (50:30:20). A medium duration high yielding rice variety Mahamaya was taken as test crop. The results revealed that combination application of inorganic fertilizer and organic manure i.e. integrated of fertilizer and manure improve chemical properties of soil like organic carbon, available N, P, and K status in soil microbial biomass in soil as compared to absolute and alone inorganic fertilizer. Application of organic (FYM, Rice residue, Green manure) with inorganic fertilizer in rice along with 50 and 75 % RDF gave higher soil organic carbon available P and MBC content of soil as compared to control. The result revealed that MBC positively significant correlated with organic carbon, available N, P and K and yield of rice.

Keywords: Rice, microbial biomass carbon, organic and inorganic fertilizer

Introduction

Rice is an important crop grown in nearly 44 million ha of land in the country with the productivity of 2.2 t/ha which is less than the productivity of many Asian countries. In Chhattisgarh, rice occupies average of 3.6 million ha with the productivity of the state ranging between 1.2 to 1.6 t/ha depending upon the rainfall. Chhattisgarh state occupies 13.51 million hectares with a gross cropped area of about 5.68 million ha. The geographical area of the state is situated between 17° 46' to 24° 6' N latitude and 80° 15' to 84° 51' E longitude. Inceptisol are shallow, well-drained, loamy soils on the gentle sloping and undulating plateau (slightly dissected) with moderate erosion and occurrence of stones. They are classified as loamy, kaolinitic, isohyperthermic, Lithic Ustropepts. Inceptisol are locally called matasi soil. They have a light texture and a shallow to moderate depth.

Soil organic matter is thus an important component of soil quality and productivity. Nevertheless, its measurement alone does not adequately reflect changes in soil quality and nutrient status (Mathers *et al.*, 2000; Chen *et al.*, 2004) [13, 4]. Measurements of biologically active fractions of organic matter, such as microbial biomass carbon (MBC) and nitrogen (MBN), and potential C and N mineralization better reflects changes in soil quality and productivity that alter nutrient dynamics (Hole *et al.*, 2005) [10]. Because it is living, the microbial biomass responds much more quickly to changing soil conditions, particularly decrease or increase in plant or animal residues, than does soil organic matter as a whole. Measurable changes in microbial biomass would thus reflect changes in soil fertility due, for example, to changes in the total pool of soil organic matter (El-Ghamry *et al.*, 2001) [5].

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The soil microbial biomass (MBC and MBN) is the active component of the soil organic pool playing an important role in nutrient cycling and plant nutrition and functioning of different ecosystems.

It is responsible for organic matter decomposition thus affecting soil nutrient content and, consequently, primary productivity in most biogeochemical processes in terrestrial ecosystems (Gregorich *et al.*, 2000; Haney *et al.*, 2001) [7, 9]. Applying organic amendments to soil not only increases the total organic carbon content and its different fractions but also has a series of effects on microbial proliferation and activity (Tejada *et al.*, 2006; Ros *et al.*, 2003) [27, 18]. Soil microbial biomass is undoubtedly a valuable tool for understanding and predicting changes in soil fertility management and associated soil conditions such as nutrient dynamics and soil reaction (Sharma *et al.*, 2004; Yougun *et al.*, 2007) [21, 32]. It has assumed greater significance and increasing interest in its determination (Azam *et al.*, 2003) [2].

Soil microbial diversity is one of the most important microbial parameters in soil. It has been demonstrated that soil microbial diversity is affected by anthropogenic disturbance (Fox and MacDonald, 2003) [6]. Inorganic fertilizers, especially nitrogen (N), phosphorus (P) and potassium (K), not only serve to maintain or improve crop yields, but their application also directly or indirectly induce changes in soil chemical, physical and biological properties. Some studies showed that chemical fertilizers increase biomass C and N, Sarathchandra *et al.* (2001) [19] reported that nitrogen and phosphate fertilizers had no significant effects on soil microbial populations and N application reduced the functional microbial diversity in pasture soils.

“Long term effect of inorganic fertilizers and organic manures on soil fertility status, microbial biomass carbon, and yield of rice on inceptisol” was undertaken with the objectives effect of integrated nutrient management practices on soil microbial biomass carbon and effect of combination of inorganic and organic treatment on growth and yield of rice crop.

Method and Materials

The field experiment was conducted at the research farm, Indira Gandhi Krishi Vishwavidyalaya, Raipur (Chhattisgarh) during *kharif*. Raipur comes under agro-climatic plain Zone of Chhattisgarh State and lie at 21°16' N latitude and 81°26' East longitude with an altitude of 289.56 m above the mean sea level. The experiment were laid out in eleven treatment combinations. T₁ -No Fertilizer, No Organic manure (Control), T₂ -50% Recommended NPK (40:30:20), T₃-75% Recommended NPK, T₄-100% Recommended NPK (80:60:40), T₅-50% Recommended NPK +50%N through Farm yard manure, T₆ -75% Recommended NPK +25%N through Farm yard manure, T₇-50% Recommended NPK +50%N through rice residue, T₈-75% Recommended NPK +25%N through rice residue, T₉-50% Recommended NPK +50%N through Green manure, T₁₀-75% Recommended NPK +25%N through Green manure, T₁₁. Conventional Farmer' Practice (50:30:20). A medium duration high yielding rice variety Mahamaya was taken as test crop with three replications. pH measured by glass electrode in 1:2.5 soil water as described by Piper (1967) [17]. The conductivity of supernatant liquid was determined by Solubridge as described by Black (1965) [3]. Organic carbon by Walkley and Black's (1934) [31] rapid titration method as described by Jackson (1967) [8]. Available nitrogen content in soil was determined by alkaline potassium permanganate method as described by

Subbiah and Asija (1956) [25]. Available phosphorus was estimated by the ascorbic acid method as described by Olsen, (1954) [16]. Absorbance readings were taken at an 882 nm wavelength using a double beam spectrophotometer. Available potassium was extractant neutral normal ammonium acetate by using flame photometer. It was described by Jackson in 1967 [8]. Microbial biomass carbon is determined by the modified fumigation-incubation method (Vance *et al* 1987) [29] in which the main aim was to see if the amounts of C which could be directly extracted from soils following fumigation were related to microbial biomass C. In this method, 40-45gm soil was weighed in to a 500ml reagent bottle and kept for fumigation. Ethanol- free chloroform was prepared immediately before fumigation. The chloroform was poured in a separating funnel and washed with concentrated H₂SO₄ (each with half the volume of chloroform) and another three times with the same volume of distilled water similarly and the bottom whitish phase was collected. All the washing was given to make the chloroform free of ethanol. The required volume of ethanol free chloroform (10-20 ml) was kept in 500 ml reagent bottle containing soil and placed in dark for 24 hrs. After 24 hours, the lid of the bottle is opened for ½ hours so that gasses pass out.

Results and Discussion

Effect of long term inorganic fertilizer and organic manure application on soil chemical properties

Soil pH

Soil pH was determined in different treatments after the harvest of rice crop and the data was presented in Table 1. The soil pH after the harvest of rice crop showed non-significant difference with respect to different organic manures and inorganic fertilizers applied. In all the treatments, there was no remarkable change in soil pH as compared to the control. However, higher value (7.5) of pH was recorded in 75% RDF treatment and lower value (7.1) of pH recorded in 75% RDF + 25% GM-N. Similar finding had been recorded by Sime (2001) [23]. Buffering action of soils does not permit to alter the soil pH. The rise in pH is ascribed to decrease in organic carbon concentration of the soil due to continuous cropping as reported by Agarwal *et al* (2010) [1] and Swarup and Yaduvashi (2000) [26] also reported that soil pH was higher in inorganic fertilizer treatment plot as compared to NPK + green manure treatment plots.

Soil EC

The data on electrical conductivity (EC) was presented in Table 1 revealed that the effect of applied organic and inorganic fertilizer on EC was statistically non significant. However, higher value (0.25dSm⁻¹) of EC was recorded in 75% RDF + 25% FYM-N treatment and lower value (0.20dSm⁻¹) of EC recorded in Farmer's practice treatment. Soil pH showed non-significant change over initial value with the applied organic manure and inorganic fertilizer treatment. The different treatment did not influence the pH and EC of soil. The values were almost constant and similar finding was also reported by Urkurkar *et al.* (2010) [30], with almost same set of treatment in rice crop.

Organic carbon

The data on soil organic carbon (SOC) after harvest of rice crop was presented in Table 1. The SOC ranges vary from 0.56 to 0.75gm kg⁻¹ amongst different treatments. The level of application of inorganic fertilizer along with organic manure significantly increased the organic carbon. After harvest of

rice, SOC was recorded highest (7.5gm kg⁻¹) in 50% RDF + 50% FYM-N, followed by 50% RDF + 50% GM-N while, lowest (5.6gm kg⁻¹) under control plots. The same finding during experimentation revealed that integrated use of inorganic fertilizer with organic manures increased the organic carbon and N, P and K status of the soil as reported by Sharma *et al.* (2009)^[22].

Table 1: Effect of long term fertilizer and manure application on soil pH, EC and organic carbon after harvest of rice

Treatments	After harvest of rice		
	pH	EC (dSm ⁻¹)	Organic carbon (gm kg ⁻¹)
T1 Control	7.3	0.22	5.6 e
T2 50% RDF (40:30:20)	7.3	0.22	6.2 d
T3 75% RDF	7.5	0.23	6.4 d
T4 100% RDF (80:60:40)	7.4	0.21	7.2 b
T5 50% RDF+50% FYM-N	7.2	0.22	7.5 a
T6 75% RDF+25% FYM-N	7.3	0.25	6.8 c
T7 50% RDF+50% RR-N	7.2	0.21	6.8 c
T8 75% RDF+25% RR-N	7.2	0.23	6.7 c
T9 50% RDF+50% GM-N	7.2	0.22	7.2 b
T10 75% RDF+25% GM-N	7.1	0.22	6.8 c
T11 Farmer practices (50:30:20)	7.3	0.2	6.6 c
SEm±	0.08	0.01	0.09
CD (P= 0.05)	NS	NS	0.27

FYM- farm yard manure, RR- rice residues, GM- green manure

Available N

The data on available N content in soil after harvest of rice crop was tabulated in Table 2. The available N varies between 160 to 272 kg/ha amongst different treatments. Application of fertilizer along with FYM and GM significantly increase the available N in soil over 100 % RDF alone treatment. Higher amount of available N (272 kg ha⁻¹) in soil was noted in 50% RDF + 50% GM-N followed by 50% RDF + 50% FYM-N and rice residues and lowest (160 kg ha⁻¹) was recorded in control. Adding green manure favored the soil conditions and might have helped in the mineralization of soil N leading to build up of increased available N.

Available P

The data on available P content in soil after harvest of rice crop was arranged in Table 2. The range of available P was vary from 8.68 to 31.37 kg/ha in various treatments. Available P content of soil was increased as compared to its initial status. Highest available P (31.37 kg ha⁻¹) was obtained with 50% RDF + 50% FYM-N followed by (28.88 kg ha⁻¹) 50% RDF+ 50% GM-N treatment and lowest (20.55kg ha⁻¹) in 50% RDF treated plot except control. When RR was incorporated in the soil, the P availability increases, but the response was not significant when compared with 50% as well as 75% RDF i.e. absolute inorganic fertilizer application. Continuous use of balanced fertilizer since 1991-92 is conducive for maintaining the soil available P. The results of the present study also revealed that higher available P content were recorded in integrated nutrient management treatments as compared to absolute control. It was also observed that successive significant increase had occurred due to increasing levels of fertilizer application along with organic manure addition in soil. Similar results have also been reported by Thakur *et al.*, (2010)^[28]. They found that exclusion and/or omission of P in the fertilizer schedule had resulted in lowering the available P content in the soil. The results also support that increasing levels of fertilizer application had resulted in substantially enhancing the available P content and so was the case with

use of FYM along with balanced dose of fertilizer. Swarup and Yaduvanshi (2000)^[26], Thakur *et al.*, (2010)^[28] have also reported the beneficial effects of organic matter on available P in soils.

Available K

The data on available K after harvest of rice crop was presented in Table 2. Available K ranged between from 207 to 264 kg/ha amongst various combination of inorganic and organic nutrient management treatment. The higher available K (264 kg ha⁻¹) was obtained with 50% RDF + 50% FYM-N and lower (207 kg ha⁻¹) in control. Application of FYM along with 50% RDF inorganic fertilizer results significantly higher amount of available N, P and K in soil as compared to 100% RDF fertilizer alone. Continuous use of N,P and K fertilizer over the years reduced the organic carbon status leading to a decline in the availability of macronutrients in soil whereas, FYM incorporation along with N,P and K fertilizers increased the organic C status of soil which consequently caused higher availability of N,P and K in soil. These findings are in agreement with those of Krishna (2003)^[12].

Table 2: Effect of continuous application of fertilizer and manure on available N, P and K content in soil after harvest of rice

Treatments	Available nutrients (kg ha ⁻¹)		
	N	P	K
T1 Control	160 h	8.68 c	207 f
T2 50% RDF (40:30:20)	207 g	20.55 bc	225 e
T3 75% RDF	238 e	22.81 b	229 e
T4 100% RDF (80:60:40)	256 d	27.87 a	260 a
T5 50% RDF+50% FYM-N	268 ab	31.37 a	264 a
T6 75% RDF+25% FYM-N	263 bc	27.58 a	247 bc
T7 50% RDF+50% RR-N	258 cd	26.22 ab	239 d
T8 75% RDF+25% RR-N	252 d	24.38 b	228 e
T9 50% RDF+50% GM-N	272 a	28.88 a	260 a
T10 75% RDF+25% GM-N	266 b	26.21 b	252 b
T11 Farmer practices (50:30:20)	224 f	23.42 b	246 c
SEm±	1.97	1.62	1.73
CD (P= 0.05)	6.0	4.77	5.1

FYM- farm yard manure, RR- rice residues, GM- green manure

Effect of long-term inorganic fertilizer and organic manure application on soil microbial biomass carbon

It was revealed that increase in application of inorganic fertilizers increased the microbial biomass carbon (Table no 4.3) in soil. Application of 50% and 100% RDF in rice significantly influenced the biomass Cover control. The 50% RDF and 50% FYM-N significantly increased the MBC than 100% RDF. The combination of inorganic fertilizer with organic manure at 50% and 75% recommended dose of fertilizer in rice showed significant increase in MBC over chemical fertilizer alone. The incorporation of green manure legumes and N fertilizer application significantly increased the microbial biomass and activities in rice-wheat system reported by Shah *et al.* (2010)^[20]. For sustainable crop production and maintaining soil quality, input of organic manure like FYM is of major importance and should be advocated in the nutrient management of intensive cropping system for improving soil fertility and biological properties of soils concluded by Moharana *et al.* (2012)^[15]. The effect was more pronounced at higher level of FYM and GM application and/or incorporation in soil. However, rice residues did not show any remarkable effect in the rice crop. The increase in MBC is the result of combination of inorganic and organic can be attributed to the readily available compound after

decomposition of these organics supplying the required substrate to microbes for their multiplication.

Table 3: Effect of different combination of the inorganic fertilizer and organic manure on soil microbial biomass carbon after harvest of rice

Treatments	Microbial biomass carbon (μgCg^{-1}) of dry soil
T1 Control	135.28 f
T2 50% RDF (40:30:20)	165.12 e
T3 75% RDF	207.71 d
T4 100% RDF (80:60:40)	237.40 c
T5 50% RDF+50% FYM-N	334.55 a
T6 75%RDF+25% FYM-N	283.20 b
T7 50%RDF+50% RR-N	184.99 e
T8 75% RDF+25% RR-N	179.56 e
T9 50% RDF+50% GM-N	327.66 a
T10 75% RDF+25% GM-N	279.44 b
T11 Farmer practices (50:30:20)	217.35 cd
SEm \pm	7.42
CD (P= 0.05)	21.90

FYM- farm yard manure, RR- rice residues, GM- green manure

Effect of different nutrient management practices on rice yield

The yield of rice increased with increasing the levels of

mineral nutrients from 50 to 100% RDF. Treatment T₉ consisting of 50% RDF + 50% GM-N as received from green manuring registered highest grain yield (70.23 q/ha) of rice which was significantly superior to the control, farmer's practice and different levels of mineral nutrients i.e. from 50 to 100 % RDF. It was because of the immobilization of nitrogen and comparable to that of 100% inorganic fertilizer treatment (T₄), 50% (T₅) and 75% (T₆) RDF +25/50% N as received from FYM and 25% N received from GM in T₁₀ respectively (Table 4). Significant residual effect of FYM and GM incorporation in soil was recorded on grain yield of rice. Thus, the use of FYM and GM with fertilizer N has helped in sustaining the yield of rice as reported by Singh *et al* (2001) [24]. Rice was found to be more responsive than rabi crops to green manuring, which might be due to direct effect of green manure in supplying nutrient to rice crop and beneficial effect on soil health as reported by Kumar and Singh (2010) [11]. Mehdi *et al.* (2011) [14] studied the comparison of Sesbania and FYM applied at 20 ton ha⁻¹ showed that Sesbania remained superior over the farm yard manure for improving the paddy and straw yield. The increased efficiency of NPK fertilizer with green manuring may be due to chemical, enzymatic and metabolic transformation of organic material, as the green manuring is continuously subject to degradation, thus more susceptible to change in metal uptake than inorganic soil fractions.

Table 4: Effect of long term inorganic fertilizer and organic manure application on rice yield

Treatments	Yield q/ha	
	Grain	Straw
T1 Control	13.13 e	23.29 e
T2 50% RDF (40:30:20)	43.54 cd	68.13 cd
T3 75% RDF	61.77 b	92.08 a
T4 100% RDF (80:60:40)	70.1 a	94.79 a
T5 50% RDF+50% FYM-N	69.27 a	93.13 a
T6 75%RDF+25% FYM-N	67.5 a	93.75 a
T7 50%RDF+50% RR-N	60.73 b	81.46 b
T8 75% RDF+25% RR-N	57.6 b	77.5 b
T9 50% RDF+50% GM-N	70.23 a	95.83 a
T10 75% RDF+25% GM-N	68.29 a	96.25 a
T11 Farmer practices (50:30:20)	51.04 c	76.46 b
SEm \pm	2.78	3.72
CD (P= 0.05)	8.15	10.90

FYM- farm yard manure, RR- rice residues, GM- green manure

Relationship of soil microbial biomass carbon with soil fertility and crop yield

Correlation coefficient between the selected various component of soil fertility with soil microbial biomass carbon (MBC) was worked out and the values of correlation coefficient are presented in table 8. Correlation analysis was performed to quantify the relationship of soil MBC with soil fertility and crop yield. This analysis was carried out to find out the contribution of various component of soil fertility to soil MBC. The correlation study revealed that soil MBC was significantly and positively correlated with organic carbon, available nitrogen, phosphorous, potassium and crop yields. It can be concluded from the above results that the highly positive significant correlation coefficient was found between organic carbon, available nitrogen, phosphorous, potassium, and crop yield and it was explained by $r = 0.82, 0.76, 0.79, 0.89, 0.76$ and 0.74 , respectively during rice season. Zhong and Cai (2005) [33] reported that the most microbial parameters were mainly correlated with soil organic carbon content rather than P and N indicating that the application of P and N did not directly affect microbial parameters in the

soil, but did so indirectly by increasing crop yields, thus promoting the accumulation of soil organic matter.

Table 5: Relationship between of soil fertility and crop yield with soil microbial biomass carbon (after 21 crop cycle)

Parameters	R-value
Microbial biomass carbon vs. organic carbon	0.82**
Microbial biomass carbon vs. available nitrogen	0.76**
Microbial biomass carbon vs. available phosphorous	0.79**
Microbial biomass carbon vs. available potassium	0.89**
Microbial biomass carbon vs. grain yield	0.76**
Microbial biomass carbon vs. straw yield	0.74**

FYM- farm yard manure, RR- rice residues, GM- green manure

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