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# Impact of Nutrient Management Technologies, Soil Biomass and Enzymatic Activities in Transplanted Rice (*Oryza sativa* L.) Under Irrigated Domains of Eastern Plain Zone in India

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## A B S T R A C T

The experiment was done during kharif season 2016 at farmer field in Bhadohi district near Varanasi to ascertain the validity of developed fertilizer adjustment equations based on Soil Test Crop Response for targeted yield of this crop. These equations were compared with other fertilizer use practices such as farmer's practice and general recommendation. Fertilizer doses for different crop under STCR based fertilizers application treatment were calculated using fertilizer adjustment equations for targeted yield of different crops. The percent increase in yield ware 17.11 and 37.79 with targeted yield 40q $ha^{-1}$ and 50q $ha^{-1}$, respectively over RDF. The remarkable net benefit of rice at location (Rs. 27426.00 and Rs. 37334.00) under treatments where plant nutrients applied as per soil test value (STCR treatment).The highest microbial biomass were recorded in$T_7$ (biomass carbon 234.80 µg $g^{-1}$) as compared to $T_1$ (biomass carbon 136.61 µg $g^{-1}$).The highest enzymatic activities were also recorded in $T_7$ (urease activity 231.45µg $g^{-1}$ soil $hr^{-1}$) as compared to $T_1$ (194.77µg $g^{-1}$ soil $hr^{-1}$) treatments. Enzymatic activities were positively and significantly correlated with content of organic carbon.Though fertilization significantly improved rice productivity over control the application of NPK and FYM in combination was found more effective in increasing rice productivity and soil nutrient status than single application of FYM or chemical fertilizer.

## Introduction

Rice is an important staple food that provides 60-70% of body calorie intake of the consumers (Barah and Pandey, 2005). To assess food security in rice consuming country of the world, rice production should be increased by 50% in this country by 2025. This additional rice will have to be produced on less land with less water, less labour and chemical. Similarly, to achieve the projected targets of 680 and 771 million tons by 2015 and 2030, respectively, the productivity of rice has to be increased through the addition of suitable integrated approaches. Rice based cropping systems are the major production system contributing to food production. Current crop production systems are characterized by inadequate and imbalanced uses of fertilizer e.g. blanket fertilizer recommendation over large domains with least regard to the variability in soil fertility and productivity. Nutrients available in soil are rarely present in adequate amount and in balanced proportion to meet the nutrient requirement of the crops. Soil test provides the actual information about the amounts of nutrients available in the soil and their imbalance, while fertilizer recommendation aims at correcting the imbalances of nutrients according to crop requirement. Several approaches have been used for fertilizer recommendation based on soil test so as to attain maximum yield per unit of fertilizer use.

Among the various approaches, the targeted yield approach has been found popular in India. The theory of formulating optimum fertilizer recommendation for targeted yield was first given by Truog (1960), which was further modified by Ramamoorthy *et al.,* (1967).Fertilizer adjustment equation developed to different crops for agro climate zones are verified for usefulness at farmer fields by conducting multi location validation trials.

The microbial population plays a vital role in ecosystem because approximately 90% of the soil processes are related with microorganisms. Soil microbial population are the driving force behind regulating soil processes such as organic matter decomposition and nutrient cycling, it is imperative to have a better understanding of the factors that regulate its size, activity, and structure (Masto *et al.,* 2006). Soils containing a high microbial diversity are characteristic of a healthy soil-plant relationship, whereas those with low microbial diversity are characterized as an unhealthy soil that often hardly responds to environmental changes (Tejada *et al.,* 2011).

The enzymatic activities of soil can be used as an indicator of soil microbial diversity in increasing biochemical reactions which are important for the life of soil micro-organisms, organic wastes decomposition, organic matter formation and nutrients cycling (Tabatabai, 1994). The microbial population dynamics is governed by interactions between plant type, climate, and management practices. The soil microbial biomass in soil system responds more effective to management practices than organic matter and is often used as an indicator of soil quality (Ge *et al.,* 2010). Soil microbial biomass is an important ecological indicator and acts as a source and sink of available nutrient for plant growth. It is supposed to be an integral part of decomposer subsystem. Soil microorganisms play a crucial role in ecosystem functions such as organic matter decomposition, nutrient cycling, transformation, mineralization etc. It also provides information regarding the organic matter decomposition, nutrient cycling, soil fertility restoration and development of ecosystem function in tropical abandoned agro ecosystems. A small change in soil microbial biomass affects directly on ecosystem stability and soil quality.

Therefore microbiological status is considered as a suitable indicator of soil health during restoration process of degraded agro-ecosystems. The microbial biomass is a living component of soil organic matter, constituting 1-5% of total organic matter content and it responds more quickly to the changes in soil conditions than Soil organic matter.

To increase the crop productivity, use of high-yielding varieties with optimum levels of inputs is very much needed, but the decision on fertilizer use would require an in-depth knowledge of the expected crop yield response to nutrient application, which is a function of crop nutrient needs, supply of nutrients from indigenous sources, and the short- and long-term fate of the fertilizer doses applied to a soil (Dobermann *et al.,* 2003).

## Materials and Methods

The experiment was conducted during kharif season of 2016 in farmer field at location Raimalpur-Village, Bhadohi District near Varanasi.

The trial was laid out in Randomized Complete Block Design (RCBD) with seven treatments and three replication at farmer's field (520 $m^2$) location during the study period. The treatments are as follows:

$T_1$: Control – NPK @ 0:0:0 kg $ha^{-1}$

$T_2$: Farmer's practice - NPK @ 100:40:40 kg $ha^{-1}$

$T_3$: General recommended dose (GRD) @ 120:60:60 NPK kg $ha^{-1}$

$T_4$: NPK application based on soil test crop response (NPK@99:48:59 kg $ha^{-1}$)

$T_5$: NPK application based on soil test crop response (NPK@145:62:88 kg $ha^{-1}$)

$T_6$: NPK application based on soil test crop response (NPK-95-47-58 kg $ha^{-1}$ & 2 t FYM)

$T_7$: NPK application based on soil test crop response (NPK-140-60-85 kg $ha^{-1}$ & 2 t FYM)

The equation used for calculating NPK recommended dose for target yield developed by Regar and Singh, 2014 for *Alluvial* soils of Varanasi region, was used on the basis of soil test value. Based on this value, the fertilizer doses for different treatments were calculated for fertilizer recommendation. Soil test based recommendation for yield target by utilizing the fertilizer adjustment equation.

Nitrogen dose (kg $ha^{-1}$) = 4.76T-0.49SN-0.34FYM-N

Where,

T = Yield target (q $ha^{-1}$) SN+ Alkaline $KMnO_4$-N

SN= Initial test value - nitrogen

FYM = Farm Yard Manure

Phosphorus dose (kg $ha^{-1}$) = 1.53T-1.41SP-0.09FYM-P

Where,

T = Yield target (q $ha^{-1}$) SP + Olsen's P (kg $ha^{-1}$)

Olsen's P = Initial soil test value- Phosphorus

FYM = Farm Yard Manure

Potassium dose (kg $ha^{-1}$) = 2.92T-0.35K-0.11FYM-K

Where,

T = Yield target (q $ha^{-1}$) SK + Amm. Ac.- K (kg $ha^{-1}$)

Amo. Ac.-K = Initial soil test value-Potassium

Using with the above equations, the quantity of fertilizer nutrients required for achieving 40 q $ha^{-1}$ and 50 q $ha^{-1}$ grain yield of rice was worked out.

Data on plant height (cm), number of tillers $hill^{-1}$, panicles $plant^{-1}$, grain and straw yield (tonne $ha^{-1}$) was recorded at maturity during the experimentation. Data was analysed statistically according to Fisher's analysis of variance technique (Steel *et al.*, 1997) and critical difference (CD) at 5% probability level was applied to compare the treatment's means.

## Experimental soil

Initial soil samples were collected from each location and analyzed for pH was determined in 1:2.5 soil-water suspension by potentiometer method (Jackson1973). Electrical conductivity was determined extract using Conductivity Bridge and expressed as dSm-1 (Jackson 1973), organic carbon (Walkely and Black, 1934), alkaline $KMnO_4$-N (Subbiah and Asija, 1956), Olsen-P (Olsen *et al.*, 1954), $NH_4OAc$-K (Hanway and Heidal, 1952), Soil biomass C, N, P Fumigation method(Edwards and Bremner 1967), Urease activity Colorimeter method (Bremner and Douglas, 1971), Alkaline Phosphatase activity Colorimeter method (Tabatabai, and Bremner (1969) and Dehydrogenase activity Colorimeter method (Casida *et al.,* 1964). The initial soil fertility status for location is shown in Table 1. The crop variety HUR 105 was used with the seed rate of 15 kg $ha^{-1}$ as the said variety is recurrently used for paddy cultivation by most of the farmers of the area. The soil was puddled at desirable field condition followed by planking. Nitrogen (N), Phosphorus (P) and Potassium (K) were applied in the form of urea, diammonium phosphatase (DAP) and muriate of potash (MOP) respectively. Whole P, K and one third of the N were side dressed at the time of transplanting, while the remaining N was top dressed in two splits at tillers initiation and pre-flowering stages respectively. The crop was harvested manually during 2$^{nd}$ week of November, 2016. After harvest of rice, soil samples were taken from the surface layer (0-15) of seven treatments and three replications. Physico-chemical properties of the initial soil samples were recorded in the following Table 1.

## Results and Discussion

The data pertaining to the grain yield of rice under different treatments at farmer field has been presented in Table 2. The treatment $T_7$ receiving 140-60-85 and 2, NPK kg $ha^{-1}$ and FYM t $ha^{-1}$ yield was significantly higher. The highest (51.30q $ha^{-1}$) yield of rice was obtained with treatment $T_7$ followed by $T_6$, $T_5$, $T_4$, $T_3$ and $T_2$; 43.60, 46.50, 38.40, 37.23, 31.40, q $ha^{-1}$, respectively and lowest (22.05 q $ha^{-1}$) was found in the treatment $T_1$. The combine use of fertilizer and organic manure on the basis of soil test value produce significantly higher yield as compared to blanket application. The Combined application of organic manure and chemical fertilizers would be quite promising not only in providing greater stability in production, but also in maintaining better soil fertility. Thus, the balanced use of fertilizer either alone or in combination with FYM is necessary for sustaining soil fertility and productivity of crop. Similarly Shah and Kumar (2014) also reported that integrated nutrient management showed significant influence on productivity of rice. The experimental field of Shri Anand Mohan Maurya, the actual yield obtained was around ±5% from targeted yield. The farmer Shri Anand Mohan Maurya, 51.30 q $ha^{-1}$ yield obtained from targeted yield of 50 q $ha^{-1}$ with higher benefit: cost ratio (3.94) as compare to farmer's practice (1.90) and General Recommendation Dose (2.39). The fertilizer recommendation for farmer practices is 100 N: 40 P: 40 K, kg $ha^{-1}$ and for 50 q $ha^{-1}$ target yield treatment recommended on the basis of soil test value is 140 N: 60 P: 85 K kg $ha^{-1}$ + 2 ton FYM. In this way treatment of targeted yield 50 q $ha^{-1}$ was found most economic treatment as compare to farmer practices and general recommendation. Similar results were also reported by Singh *et al.,* (2015).

## Effect of different treatments on nutrient uptake by rice

Effects of different treatments on nutrient uptake by rice were recorded in Table 4.

**Table.1** Physico-chemical properties of the initial soil samples

| S.No. | Characteristics | Value |
|---|---|---|
| 1. | Texture | |
| | Sand (%) | 52.30 |
| | Silt (%) | 30.60 |
| | Clay (%) | 17.10 |
| | Textural class | Sandy loam |
| 2. | pH (1:2.5) Soil water suspension | 8.0 |
| 3. | EC (1:2.5) Soil water suspension ($dSm^{-1}$) | 0.26 |
| 4. | Organic carbon (%) | 0.45 |
| 5. | Available Nitrogen (kg $ha^{-1}$) | 183 |
| 6. | Available Phosphorus (kg $ha^{-1}$) | 12 |
| 7. | Available Potassium (kg $ha^{-1}$) | 163 |
| 8. | Soil biomass Carbon (µg $g^{-1}$) | 134 |
| 9. | Soil biomass Nitrogen (µg $g^{-1}$) | 25 |
| 10. | Soil biomass Phosphorous(µg$g^{-1}$) | 9 |
| 11. | Urease Activity (µg $g^{-1}$ soil $hr^{-1}$) | 189 |
| 12. | Dehydrogenase activity (µg TPF $g^{-1}$ soil $h^{-1}$) | 132 |
| 13. | Alkaline phosphatase activity (µg p- nitrophenol $g^{-1}$ soil $h^{-1}$) | 40 |

**Table.2** Effect of different treatments on grain and straw yield of rice

| Treatments | Grain yield (q $ha^{-1}$) | Straw yield (q $ha^{-1}$) |
|---|---|---|
| **Shri Anand Mohan Maurya** | | |
| $T_1$ | 22.05 | 33.91 |
| $T_2$ | 31.40 | 45.46 |
| $T_3$ | 37.23 | 52.17 |
| $T_4$ | 38.40 | 59.44 |
| $T_5$ | 46.50 | 71.36 |
| $T_6$ | 43.60 | 63.89 |
| $T_7$ | 51.30 | 72.28 |
| **CD at 5 %** | **2.32** | **3.57** |

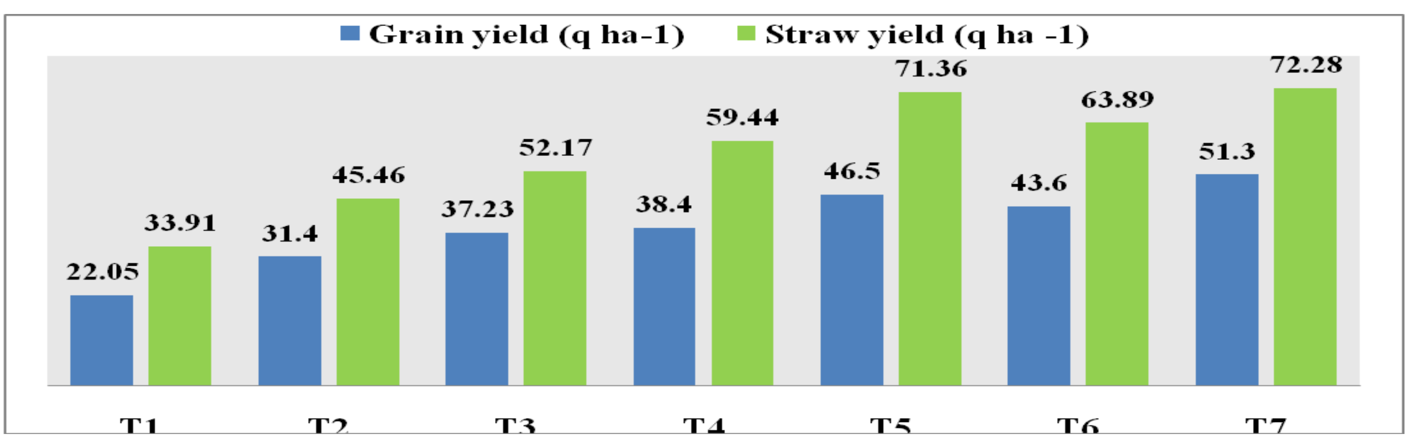

**Table.3** Effect of different treatments on net benefit and economics of rice crop

| Fertilizer dose NPK(kg ha$^{-1}$) & FYM (t ha$^{-1}$) | Actual mean yield (kg ha$^{1}$) | Additional yield (kg ha$^{1}$) | Value of additional yield (Rs.) | Cost of fertilizer (Rs.) | Net benefit (Rs.) | B/C ratio | Deviation in yield (%) | Increase % yield Over RDF (%) |
|---|---|---|---|---|---|---|---|---|
| $T_1$ (0-0-0) | 2205 | - | - | - | - | - | | |
| $T_2$ (100-40-40) | 3140 | 935 | 14960 | 5154 | 9806 | 1.90 | | |
| $T_3$ (120-60- 60) | 3723 | 1518 | 24288 | 7164 | 17124 | 2.39 | | |
| $T_4$ (99-48-59) | 3840 | 1635 | 26160 | 5580 | 20580 | 3.69 | -4.00 | 3.14 |
| $T_5$ (145-62-88) | 4650 | 2445 | 39120 | 8089 | 31031 | 3.84 | -7.00 | 24.90 |
| $T_6$ (95-47-58 & 2) | 4360 | 2155 | 34480 | 7054 | 27426 | 3.89 | 9.00 | 17.11 |
| $T_7$ (140-60-85&2) | 5130 | 2925 | 46800 | 9466 | 37334 | 3.94 | 2.60 | 37.79 |

Paddy@Rs.16.00/kg, N@Rs. 15.39/kg, $P_2O_5$@Rs 56.25/kg, $K_2O$@ Rs 26.66/kg, FYM @Rs 0.75/kg

**Table.4** Effect of different treatments on nutrient uptake by rice

| **Shri Anand Mohan Maurya** | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| **Treatments** | **Grain uptake (kg ha$^{-1}$)** | | | **Straw uptake (kg ha$^{-1}$)** | | | **Total uptake (kg ha$^{-1}$)** | | |
| | **N** | **P** | **K** | **N** | **P** | **K** | **N** | **P** | **K** |
| $T_1$ | 27.56 | 4.63 | 5.29 | 10.29 | 0.72 | 45.53 | 37.76 | 5.34 | 50.82 |
| $T_2$ | 46.79 | 6.91 | 7.85 | 15.00 | 1.50 | 65.46 | 61.79 | 8.41 | 73.31 |
| $T_3$ | 59.20 | 9.68 | 10.05 | 18.78 | 1.93 | 81.39 | 77.98 | 11.61 | 91.44 |
| $T_4$ | 64.51 | 10.37 | 11.90 | 22.59 | 2.44 | 94.52 | 87.10 | 12.81 | 106.42 |
| $T_5$ | 79.52 | 14.88 | 17.21 | 29.31 | 3.50 | 124.18 | 109.49 | 18.38 | 141.38 |
| $T_6$ | 75.43 | 13.52 | 14.39 | 25.20 | 3.00 | 103.51 | 101.63 | 16.53 | 117.90 |
| $T_7$ | 90.29 | 17.96 | 20.55 | 31.80 | 3.69 | 128.67 | 122.09 | 21.64 | 150.22 |
| **C D at 5 %** | **0.83** | **0.42** | **0.39** | **0.698** | **0.061** | **1.232** | **1.56** | **1.41** | **1.11** |

**Table.5** Effect of different treatments on soil fertility of post-harvest soil

| **Treatments** | **pH** | **EC (dSm$^{-1}$)** | **OC (%)** | **N** | **P** | **K** |
|---|---|---|---|---|---|---|
| | | | | **(kg ha$^{-1}$)** | | |
| $T_1$ | 8.29 | 0.13 | 0.39 | 185.66 | 14.11 | 165.51 |
| $T_2$ | 8.25 | 0.16 | 0.43 | 188.25 | 16.88 | 168.26 |
| $T_3$ | 8.31 | 0.32 | 0.47 | 194.22 | 17.96 | 173.47 |
| $T_4$ | 8.38 | 0.22 | 0.51 | 200.17 | 21.22 | 179.12 |
| $T_5$ | 8.16 | 0.25 | 0.55 | 209.77 | 24.16 | 185.19 |
| $T_6$ | 8.31 | 0.18 | 0.53 | 207.86 | 22.19 | 181.41 |
| $T_7$ | 7.94 | 0.29 | 0.59 | 215.33 | 26.49 | 187.33 |
| CD at 5% | 0.156 | 0.05 | 0.054 | 1.42 | 0.573 | 0.624 |

**Table.6** Effect of different treatments on soil fertility of post-harvest soil

| Treatments | Soil biomass-C (µg g-$^{1}$) | Soil biomass- P (µg g-$^{1}$) | Soil biomass-N (µg g-$^{1}$) | Urease activity (µg g-$^{1}$ soil hr-$^{1}$) | Dehydrogenase activity (µg TPF g$^{-1}$ soil h$^{-1}$) | Alkaline phosphatase activity (µg p-nitrophenol g$^{-1}$ soil h$^{-1}$) |
|---|---|---|---|---|---|---|
| $T_1$ | 136.61 | 10.40 | 28.10 | 194.77 | 133.57 | 41.23 |
| $T_2$ | 176.80 | 12.73 | 33.70 | 205.90 | 140.30 | 58.30 |
| $T_3$ | 187.72 | 14.00 | 38.43 | 214.13 | 147.71 | 77.83 |
| $T_4$ | 202.30 | 17.60 | 45.62 | 219.03 | 156.50 | 81.07 |
| $T_5$ | 230.40 | 20.10 | 52.40 | 229.08 | 164.57 | 104.51 |
| $T_6$ | 206.89 | 18.70 | 49.96 | 220.59 | 156.12 | 92.26 |
| $T_7$ | 234.80 | 23.60 | 54.26 | 231.45 | 177.39 | 109.27 |
| CD@5% | **2.14** | **1.68** | **0.48** | **7.67** | **12.45** | **0.79** |

The uptake of nutrients in rice crop was found maximum in treatment $T_7$ (122.09kg ha$^{-1}$) and minimum in treatment $T_1$ (37.76 kg ha$^{-1}$). The treatment $T_1$ was found to be significantly inferior to overall treatments. The increment in nitrogen uptake was probably due to improvement in soil condition due to application of FYM, make it easy to absorb nutrient by root. Good soil condition encouraged the proliferation of roots and improved synchrony between supply and plant demand, which in turn draw more nutrients from larger area and greater depth (Singh *et al.*, 2013).

## Effect of different treatments on soil fertility of post-harvest soil

The data related to soil pH under different treatments have been presented in Table 5. In general the pH of soil slightly decrease from initial value and (8.2) at all sites. The pH of soil of all two locations ranged between 8.0 and 8.19, it was slightly decrease in treated plots but not changed in control plots. The lowest soil pH value was observed in treatment $T_7$ in all experimental sites. The highest soil pH value was recorded in treatment $T_1$ (control). The value of Organic carbon, available nitrogen, phosphorous and potassium was found increasing trend to targeted yield $T_7$. This may be due to the fact that the application of higher amount of nitrogenous fertilizer (urea) for obtaining higher targeted yield. Hydrolysis of urea in soil reduces soil pH and application of farm yard manure increases microbial activity in soil, microbes releases organic acids during decomposition of organic matter, it was also decrease soil $P^H$. The overall treatment effect was found to be non-significant.

## Effect of different treatments on soil fertility of post-harvest soil

In the Table 6, it was found that the minimum value of biomass carbon (136.61 µg g$^{-1}$) was recorded in control $T_1$ whereas in treatment $T_7$, it was found higher value (234.80 µg g$^{-1}$), as compare to other treatments, and same trends were found in case of soil biomass phosphorous and soil biomass nitrogen respectively. Soil microbial biomass is the living component of soil organic matter. As organic matters are the preferred energy source for the microorganisms, ecosystems with high organic substances tend to have higher microbial biomass contents as well as its activities. Moreover, reduction in microbial biomass and enzyme activities due to excessive cultivation practices have been reported earlier (Gupta and Germida, 1988). The minimum value of Urease enzyme activity was found (194.77 µg g$^{-1}$ soil h$^{-1}$) in $T_1$ (control) however, in treatment $T_7$ it was found higher value (231.45 µg g$^{-1}$ soil h$^{-1}$). For Alkaline phosphatase enzyme activity and Dehydrogenase enzyme activity, it was reported that the value shows increasing trends from control $T_1$ to $T_7$ treatments respectively. Such a pattern of impact may result in a relatively long-term effect on crop production. Poultry manure applied to a rice field at 120 or 180 kg N $ha^{-1}$ showed a residual effect on wheat, which followed rice, equivalent to 40 kg N $ha^{-1}$ (Singh *et al.*, 1997). A study by Brzezinska *et al.*, (1998) was reported that soil moisture content and temperature influence dehydrogenase activity indirectly by affecting the soil redox status. After flooding the soil, the amount of oxygen present in soil rapidly decrease so that a shift of the activity from aerobic to anaerobic microorganisms takes place.

It was concluded from the present investigation that the percent achievement of the targeted yield of all the two verification trials was within ±5% variation proving the validity of the equations for prescribing integrated fertilizer doses for rice. The grain yield of rice from the two verification trials indicated that STCR-INM 40 and 50q $ha^{-1}$ (target yield) was found significantly higher grain yield over all other treatments, whereas blanket fertilizer recommendation (farmer practice) recorded significantly lower yield. Among the treatments, STCR-INM recorded relatively higher benefit: cost ratio 3.87, 3.94 and 38.70, 37.79 percent achievement than other treatments respectively. The results of this study confirmed that application of organic and inorganic fertilizers alter rice productivity and soil biological properties. The application of chemicals fertilizer and FYM were the most effective for increasing rice productivity and soil nutrient balance than sole chemical fertilizer or other amendments. Fertilization had a significantly beneficial impact on soil microbial properties. Farm yard manure and along with chemicals fertilizer application significantly improved soil microbial and enzymatic activity in soil. Based on data, it could be concluded that the combined application of chemical and organic (FYM) fertilizers @ 2t/ha could be rational strategy to sustain soil productivity as well as improving soil health status than the sole chemical fertilizer or organic (FYM) fertilizer application.

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