

Original Research Article

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## Effect of Nutrient Management and Crop Establishment Methods of Rice on Biological Properties of Soil

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### ABSTRACT

A field experiment was conducted at Research Farm, Dr. RPCAU Pusa, Bihar during *khari* 2018 on calcareous sandy loam soil, having pH 8.57, medium in soil organic carbon content (0.65 %), EC 0.35 dSm<sup>-1</sup>, available nitrogen (195 kg/ha), available phosphorus (26.63 kg/ha) and available potassium (134 kg/ha). Experiment was laid-out in split-plot design and replicated thrice. Main-plot included three crop establishment methods, viz. dry direct-seeded rice (DSR-dry), wet direct-seeded rice (DSR-wet) and puddled transplanted rice (TR). In sub-plots, five nutrient management methods T<sub>1</sub>- 100% STCR Based Dose of Fertilizer + ZnSO<sub>4</sub> @ 25 kg ha<sup>-1</sup> (DF), T<sub>2</sub>-75% DF + 25% STCR based Recommended Dose of Nitrogen (RDN) through Vermicompost, T<sub>3</sub>-100% STCR based RDN through Vermicompost, T<sub>4</sub>- 100% DF + 50% STCR based RDN through Vermicompost and T<sub>5</sub>-50% DF + 25% STCR based RDN through Vermicompost. The post-harvest soil was analysed to evaluate the effect of different nutrient management methods on soil microbial biomass Carbon (SMBC), soil microbial biomass Nitrogen (SMBN), Microbial population and Dehydrogenase Enzyme (DH) activity under the three different establishment methods. The results indicated that fungal and bacterial population was higher in transplanted rice while actinomycetes population was higher in DSR-dry. The microbial population count was highest under T<sub>3</sub>-100% RDN followed by T<sub>4</sub>-100% DF + 50% RDN. The DH, MBC and MBN recorded higher values of 28.74 µg TPF g<sup>-1</sup> hr<sup>-1</sup>, 292.6 mg kg<sup>-1</sup> and 32.20 mg kg<sup>-1</sup> respectively under transplanted rice whereas, DSR-dry recorded lower value. The DH, SMBC and SMBN were significantly influenced by the application of T<sub>3</sub>-100% RDN which recorded 33.64 µg TPF g<sup>-1</sup> hr<sup>-1</sup>, 317.1 mg kg<sup>-1</sup> & 33.27 mg kg<sup>-1</sup> respectively while significantly lower value was recorded with T<sub>1</sub>-100% DF 20.12 µg TPF g<sup>-1</sup> hr<sup>-1</sup>, 249.1 mg kg<sup>-1</sup> and 27.36 mg kg<sup>-1</sup> respectively. Therefore it may be concluded that addition of organics (vermicompost) led to improvement of microbial as well as enzymatic activity which was more pronounced in DSR-wet and Transplanted rice.

#### Keywords

Nutrient Management, DSR, Transplanting, MBC, Vermicompost

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## Introduction

Use of high energy agricultural inputs like fertilizers and pesticides cause environmental hazards, so it is desirable to develop a sustainable production system that give optimum productivity with minimum environmental pollution (Singh *et al.*, 2010). Microbes harbouring rhizosphere of crops provide benefits to crops through better nutrient availability by way of atmospheric N<sub>2</sub> fixation or solubilizing fixed mineral forms of nutrients (Pandey *et al.*, 2010). Use of integrated nutrient management yields maximum counts and establishment of microbes in soil rather than sole application of chemical fertilizer treatments (Kumar *et al.*, 2014).

Vermicompost is a product derived from the accelerated biological degradation of organic wastes by earthworms and microorganisms. It is a low cost technology, environment-friendly process used to treat organic waste. The process accelerates the rates of decomposition of the organic matter, alter the physical and chemical properties of the material, leading to a humification effect in which the unstable organic matter is fully oxidized and stabilized (Orozco *et al.*, 1996). The end product, commonly referred as vermicompost is greatly humified through the fragmentation of the parent organic materials by earthworm and colonization by microorganisms (Edwards and Neuhauser, 1988). During this process, the important plant nutrients in the material (particularly the nitrogen, potassium, phosphorus and calcium) are released and converted through microbial action into forms that are much more soluble and available to plants than those in the parent compounds (Ranganathan, 2006).

Soil microbial biomass provides a measure of the quantity of living microbial biomass present in the soil and accounts for 1-5% of

the total soil organic matter (Smith and Paul, 1990). Soil microbial biomass acts as a source or sinks of available nutrients, and plays a critical role in nutrient transformation in terrestrial ecosystems (Singh *et al.*, 1989). Change in the microbial biomass affects soil organic matter turnover and soil microbial activity which has a direct influence on ecosystem stability and fertility. Use of reduced tillage, residue retention and INM recycling C & N leading to higher microbial biomass C, N and dehydrogenase activity (Yadav *et al.*, 2017).

It is a well-known fact that more biologically active soils are characterized by higher microbial biomass leading to enhanced soil enzyme activities and soil respiration (Doran *et al.*, 1996). Hence, maintenance of soil fertility is essential to improve and sustain crop yield and soil organic carbon (SOC) (Stark *et al.*, 2007). However, organic amendments affect soil biological processes by effecting microbial functioning, composition, and population (Marschner *et al.*, 2003). Organic manure increases soil microbial biomass (Peacock *et al.*, 2001), and enzyme activities along with SOC and concentration of other nutrients such as nitrogen (Crecchio *et al.*, 2001).

Soil enzymes allow microbes to access energy and nutrients present in complex substances through nutrient mineralization and humification processes (Allison and Vitousek, 2005). The dehydrogenase depicts the direct oxidative capability of viable microorganisms present in the soil and is indicative for microbial activities (Trevors, 1984).

## Materials and Methods

The field experiment was carried out during *Kharif* seasons in 2017-18 at Research Farm, Dr. Rajendra Prasad Central Agricultural University, situated in Samastipur district of

Bihar at an altitude of 52.0 m and between 25.98<sup>0</sup> N latitude and 85.67<sup>0</sup> E longitudes. The soil of experimental field was calcareous sandy loam in texture class (56.84% Sand, 31.35 % silt and 11.79% clay) and alkaline in reaction (pH 8.57). It was moderately fertile, medium in soil organic carbon content (0.65 %), electrical conductivity (EC) 0.35 dSm<sup>-1</sup>, low in available nitrogen (195 kg/ha), medium to high in available phosphorus (26.63 kg/ha) and medium in available potassium (134 kg/ha).

The experiment was laid-out in a split-plot design (SPD). The main-plot treatments included three crop establishment methods, viz. puddle transplanted rice (M<sub>1</sub>-TPR), wet direct-seeded rice (M<sub>2</sub>-DSR-wet) dry direct seeded rice (M<sub>3</sub>-DSR-dry). In sub-plots, five different nutrient management methods were T<sub>1</sub> (100% STCR Based Dose of Fertilizer + ZnSO<sub>4</sub>@ 25 kg ha<sup>-1</sup>), T<sub>2</sub> (75% DF + 25% STCR based Recommended Dose of Nitrogen through Vermicompost), T<sub>3</sub> (100% STCR based Recommended Dose of Nitrogen through Vermicompost), T<sub>4</sub> (100% DF + 50% STCR based Recommended Dose of Nitrogen through Vermicompost) and T<sub>5</sub> (50% DF + 25% STCR based Recommended Dose of Nitrogen through Vermicompost) were replicated thrice under each method. The soil samples collected from rhizosphere of rice at post harvesting stage were analysed for microbial population by Plate count method using serial dilution (SubbaRao, 1988), SMBC by Jenkinson and Ladd, 1981, SMBN by Brooks *et al.*, 1985 and DH by Casida *et al.*, 1964.

## Results and Discussion

Microbial population (Table-1) of soil after harvest of rice was significantly influenced due to different establishment methods and nutrient management. The maximum number of fungi population was recorded under M<sub>1</sub>-

Transplanted rice (30.63 cfu g<sup>-1</sup>) which was significantly higher over DSR treatments. Among the sub-plot treatments fungal population followed the order M<sub>1</sub>> M<sub>2</sub>> M<sub>3</sub>. The maximum population of fungi was observed under T<sub>3</sub>-100% RDN (33.30 cfu g<sup>-1</sup>) and T<sub>4</sub>-100% DF + 50% RDN (33.30 cfu g<sup>-1</sup>) and minimum population of fungi was found under T<sub>1</sub>-100% DF (22.91 cfu g<sup>-1</sup>) was significantly lower. The fungal population recorded an increase of 4.10 to 45.38 % under organic amended treatments as compared inorganic alone. This might be due to acidic environment created by the application of organics (Fig. 1). The maximum actinomycetes population was recorded under M<sub>3</sub>-DSR-dry (63.27 cfu g<sup>-1</sup>) which was significantly superior to M<sub>1</sub>-Transplanted rice (60.01 cfu g<sup>-1</sup>) and M<sub>2</sub>-DSR-wet (55.34 cfu g<sup>-1</sup>) was at par with M<sub>1</sub>-Transplanted rice. Among nutrient management systems, maximum population of actinomycetes were found under T<sub>3</sub>-100% RDN (70.49 cfu g<sup>-1</sup>) which was significantly superior to rest of the treatments and minimum actinomycetes population was recorded under T<sub>1</sub>-100% DF (49.16 cfu g<sup>-1</sup>). The percentage increase in the population of actinomycetes recorded an increase of 8.90 to 43.38 % under organic amended treatments as compared to chemical alone (Fig.-1). The maximum population of bacteria was found under M<sub>1</sub>-Transplanted rice (49.60 cfu g<sup>-1</sup>) which was significantly superior to M<sub>3</sub>-DSR-dry (43.38 cfu g<sup>-1</sup>) and at par with M<sub>2</sub>-DSR-wet (46.44 cfu g<sup>-1</sup>) was at par with M<sub>1</sub>-Transplanted rice. Among treatments the maximum population of bacteria was found under T<sub>3</sub>-100% RDN (54.54 cfu g<sup>-1</sup>) followed by T<sub>4</sub>-100% DF + 50% RDN (51.47 cfu g<sup>-1</sup>) which was at par with it and minimum population of bacteria was found under T<sub>1</sub>-100% DF (39.32 cfu g<sup>-1</sup>). The bacterial population (Fig.-1) under organic treatments recorded an increase of 6.89 to 38.70 % over inorganic treatments (RDF). In case of different establishment

methods of rice crop, higher bacterial and fungi population were found under M<sub>1</sub>-Transplanted rice might be due to more quantity of organic matter available for microbial population but higher actinomycetes population was observed under M<sub>3</sub>-DSR-dry. Actinomycetes preferred in slight alkaline pH and dry conditions compare to wet. Kumar *et al.* 2015 also reported similar results. The overall increase in microbial population was more under T<sub>3</sub>-100% RDN and T<sub>4</sub>-100% DF + 50% RDN having organic alone and in combination respectively. This might be due to the congenial soil atmosphere provided by the integrated approach which would sustain the fertility for long period. The results are in agreement with other studies on long-term experiments that have shown effects on microbial biomass and activity and also shift in microbial community after addition of organic amendments Marschner *et al.*, (2003); Bohme *et al.*, (2005). Venkateswarlu and Srinivasarao, (2004) reported that both the microbial population as well as its diversity index increased in presence of FYM than inorganic fertilization and control. This may be related in our study to higher load of heterotrophic bacterial, fungal, actinobacterial, and denitrifying bacterial populations in vermicompost amended soil followed by INM. Similar result was found by Preethi *et al.*, (2013).

The highest dehydrogenase enzyme activity was recorded under M<sub>1</sub>-Transplanted rice (28.74  $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$ ) followed by M<sub>2</sub>-DSR-wet (27.17  $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$ ) which was at par with it and significantly superior to M<sub>3</sub>-DSR-dry (25.16  $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$ ). The Dehydrogenase activity is generally used as an indicator of biological activity in soil as this enzyme is known to oxidize soil organic matter. The Dehydrogenase activity was found highest under transplanted rice shows that the soil in the treatment had more potential to support biochemical processes

which are essential for maintaining fertility as well as soil health. Similar result was reported by Kumar *et al.*, (2015). Nutrient management systems indicated significant effect on dehydrogenase enzyme activity, the highest dehydrogenase enzyme activity was found under T<sub>3</sub>-100% RDN (33.64  $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$ ) followed by T<sub>4</sub>-100% DF + 50% RDN (31.20  $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$ ) which was at par with it and lowest dehydrogenase enzyme activity was found under T<sub>1</sub>-100% DF (20.12  $\mu\text{g TPF g}^{-1} \text{hr}^{-1}$ ). The performance of soil enzymes as biocatalysts of specific reactions as influenced by incorporation of organic amendments to soil added as the material may contain intracellular and extracellular enzymes which encourage microbial activity in the soil (Pascual *et al.*, 1999). The improved soil enzyme and biological activities in our study are believed to be direct indicators of the improvement of soil fertility caused from the incorporation of vermicompost, which helps to increase nutrient availability. Similar result was observed by Preethi *et al.*, (2013).

The maximum MBC was found under Transplanted Rice (292.6  $\text{mg kg}^{-1}$ ) followed by DSR-wet (286.8  $\text{mg kg}^{-1}$ ) and DSR-dry (270.4  $\text{mg kg}^{-1}$ ). Treatment T<sub>3</sub>-100% RDN (317.1  $\text{mg kg}^{-1}$ ) recorded maximum MBC which was significantly superior to rest treatments and least MBC was recorded under T<sub>1</sub>-100% DF (249.1  $\text{mg kg}^{-1}$ ). The highest soil microbial biomass nitrogen was recorded in M<sub>1</sub>-Transplanted rice (32.20  $\text{mg kg}^{-1}$ ) followed by M<sub>2</sub>-DSR-wet (30.31  $\text{mg kg}^{-1}$ ) which was at par with it and M<sub>3</sub>-DSR-dry (28.18  $\text{mg kg}^{-1}$ ) was significantly lower. The highest soil microbial biomass nitrogen was found under T<sub>3</sub>-100% RDN (33.27  $\text{mg kg}^{-1}$ ) followed by T<sub>4</sub>-100% DF + 50% RDN (32.18  $\text{mg kg}^{-1}$ ) which was at par with it. The least soil microbial biomass nitrogen was recorded under treatment T<sub>1</sub>-100% DF (27.36  $\text{mg kg}^{-1}$ ) which was at par with it T<sub>5</sub>-50% DF + 25% RDN (28.37  $\text{mg kg}^{-1}$ ).

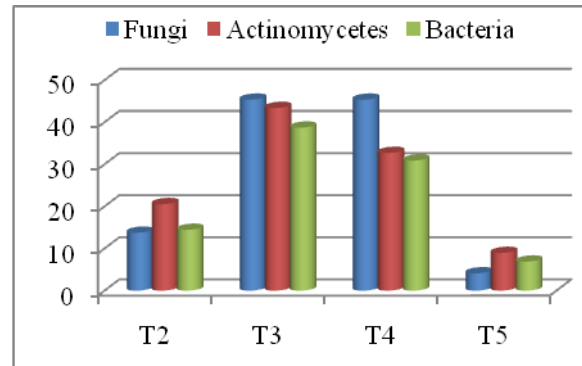
**Table.1** Effect of nutrient management and crop establishment methods on soil microbiological properties at post-harvest of rice

Establishment methods of rice crop	Fungi (10 <sup>4</sup> )cfu g <sup>-1</sup>	Actinomycetes (10 <sup>5</sup> )cfu g <sup>-1</sup>	Bacteria (10 <sup>6</sup> )cfu g <sup>-1</sup>	Dehydrogenase (µg TPF g <sup>-1</sup> hr <sup>-1</sup> )	MBC (mg kg <sup>-1</sup> )	MBN (mg kg <sup>-1</sup> )
M <sub>1</sub> -Transplanted rice	30.63	55.34	49.60	28.74	292.6	32.20
M <sub>2</sub> -DSR-wet	27.49	60.01	46.44	27.17	286.8	30.31
M <sub>3</sub> -DSR-dry	24.26	63.27	43.38	25.16	270.4	28.18
SEm±	<b>0.27</b>	<b>1.49</b>	<b>1.13</b>	<b>0.63</b>	<b>3.14</b>	<b>0.44</b>
CD (0.05)	<b>1.12</b>	<b>6.03</b>	<b>4.59</b>	<b>2.56</b>	<b>12.6</b>	<b>1.78</b>
<b>Nutrient Management</b>						
T <sub>1</sub> -100% DF	22.91	49.16	39.32	20.12	249.1	27.36
T <sub>2</sub> -75% DF + 25% RDN	26.06	59.26	45.00	26.04	276.6	29.96
T <sub>3</sub> -100% RDN	33.30	70.49	54.54	33.64	317.1	33.27
T <sub>4</sub> -100% DF + 50% RDN	33.30	65.24	51.47	31.20	304.0	32.18
T <sub>5</sub> -50% DF + 25% RDN	23.85	53.56	42.03	24.12	269.5	28.37
SEm±	<b>0.76</b>	<b>2.89</b>	<b>1.12</b>	<b>0.86</b>	<b>4.42</b>	<b>0.68</b>
CD (0.05)	<b>2.25</b>	<b>8.49</b>	<b>3.30</b>	<b>2.54</b>	<b>12.9</b>	<b>2.0</b>

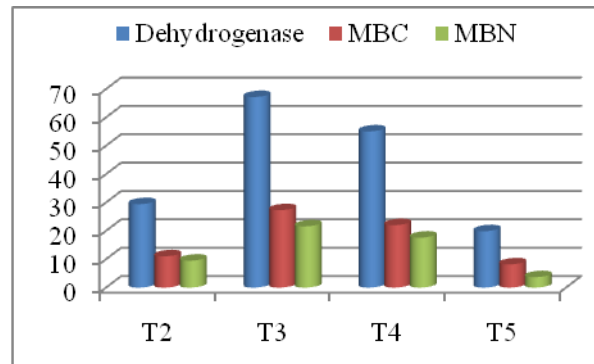
**Table.2** Grain, Straw yield (q ha<sup>-1</sup>) & Nitrogen uptake of rice as influenced by different nutrient management system and crop establishment methods

Establishment methods of rice crop	Grain Yield (q ha <sup>-1</sup> )	Straw Yield (q ha <sup>-1</sup> )
M <sub>1</sub> -Transplanted rice	51.0	60.8
M <sub>2</sub> -DSR-wet	48.5	58.5
M <sub>3</sub> -DSR-dry	46.2	56.3
SEm±	0.42	0.59
CD (0.05)	1.71	2.38
<b>Nutrient Management</b>		
T <sub>1</sub> -100% DF	48.9	58.3
T <sub>2</sub> -75% DF + 25% RDN	49.7	60.1
T <sub>3</sub> -100% RDN	47.1	57.0
T <sub>4</sub> -100% DF + 50% RDN	52.1	62.7
T <sub>5</sub> -50% DF + 25% RDN	44.9	54.5
SEm±	1.28	1.21
CD (0.05)	<b>3.76</b>	<b>3.56</b>

**Fig.1** Percent increase in microbial population of organic treatments as compared to RDF treatments (T<sub>1</sub>) at harvest rice



**Fig.2** Percent increase in soil biological properties of organic treatments as compared to RDF treatments (T<sub>1</sub>) at harvest rice



The dehydrogenase, MBC & MBN (Fig.-2) also recorded an increase ranging from 19.88 to 67.19 % in dehydrogenase activity, 8.10 to 27.29 % in MBC and 3.60 to 21.60 % in MBN under organically amended treatments ((75% DF + 25% RDN, T<sub>3</sub>-100% RDN, T<sub>4</sub>-100% DF + 50% RDN&T<sub>5</sub>-50% DF + 25% RDN) as compared to inorganic alone (T<sub>1</sub>-100% DF).In general, different organic amendments along with inorganic NPK showed good MBC than inorganic application and control. This increase in soil MBC can be ascribed to the incorporation of simply degradable materials, which encouraged microbial activity (Tejada *et al.* 2006). The readily metabolizable C and N in organic manure in addition to increasing root biomass and root exudates leads to better crop growth

which is most influential factor contributing to microbial biomass increase. Similar results have also been reported by several other workers Kaur *et al.*, (2005) and Preethi *et al.*, (2013).

### Grain and straw yield

The transplanted method of establishment and T<sub>4</sub>-100% DF + 50% RDN recorded significantly higher grain and straw yield (Table- 2) of rice which was followed by DSR-wet and T<sub>2</sub>-75% DF + 25% RDN under method of establishment and nutrient management respectively. The higher grain yield was recorded under transplanted rice due to availability of more nutrients, light, space and moisture as puddling also restrict

percolation losses. Higher grain yield under transplanting method were also reported by Mallareddy and Padmaja, (2013), Jaiswal and Singh, (2001) and Kumar *et al.*, (2018). In case of nutrient management higher grain and straw yield under T<sub>4</sub>-100% DF + 50% RDN and T<sub>2</sub>-75% DF + 25% RDN might be due to improvement in nutrient supply with more organics, which improved the soil physico-chemical and biological properties as evident from the results obtained (Tab.1 ; Fig. 1 & 2). The improved biological properties provided congenial atmosphere and essential food for microbes ultimately leading to enhanced fertility and better yield.

Therefore, it may be concluded from the present study that the micro environment of the soil was better under transplanted and DSR-wet rice which had more number of microbes as well as improved enzymatic activity. Similar the use of organics alone or in combination enhanced the microbial and enzymatic activity leading to higher yields.

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