Response of Graded Fertility Levels and Zinc Application of OrganicManure on Physiochemical and Biological Properties of Soil in Rice Crop

Abstract

The field experiment was conducted during Kharif season 2022 at Student's Instructional farm of Acharya Narendra Deva University of Agriculture and Technology Kumarganj, Ayodhya Uttar Pradesh, India. The experiment was laid out in Randomized Block Design (RBD) with three replications and ten treatments. The experiment comprised of ten treatments viz., T_1: Control, T_2: 100% RDF (150, 60, 40 N, P_2O_5, K_2O kg ha^{-1}), T_3: 100% RDF + 25 kg $ZnSO_4$ ha^{-1} soil application, T_4: 100% RDF + 0.5% $ZnSO_4$ spray at tillering stage, T_5: 100% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage, T_6: 75% RDF + 25 kg $ZnSO_4$ ha-^{1} soil application, T_7: 75% RDF + 0.5% $ZnSO_4$ spray at tillering stage, T_8: 75% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage, T_9: 75% RDF + 25% FYM-N +0.5% $ZnSO_4$ spray at tillering stage + PI stage and T_{10}: 75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha-^{1} soil application. The application of 75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} soil application has non-significantly effect on Bulk density, pH, Electrical Conductivity of soil after harvest of rice crop. The application of 75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} soil application has significantly influenced Organic carbon, Available N, P, K and Zn in soil.

Keyword: Rice, Zinc Application, FYM, Soil Fertility, Microbial Population, Enzymes, CFU (Colony Forming Unit) and SFU (Spore Forming Unit).

Introduction

Rice (*Oryza sativa* L.) is one of the most important stable food crops in the world. It is a member of the Poaceae family and genus *Oryza*. It is the most significant and widely produced food crop, growing abundantly in tropical and subtropical climates, and it supplies one in three people on earth with half of their daily nourishment (Kumar *et al*., 2023). In India produced 122.27 million tonnes of rice in 2020–21 with a productivity of 2713 kg per hectare on an area of 43.82 Mha. In Uttar Pradesh, productivity was 2759 kg ha^{-1} under 19.93 Mha area in 2020–21, while production was 15.66 million tonnes (Anonymous, 2021).The Asian continent produces and consumes almost 90% of the world's rice .It is a calorie-dense diet with a 75% starch, 6-7% protein, 2-2.5% fat, 0.8% cellulose, and 5-9% ash content

(Muthayya*et al*., 2014).The micronutrient zinc has been the one most nutrients for the crops, particularly rice, have required in appropriate amounts. Zinc is essential for metabolism and helps in the production of nodules, which are necessary for N-fixation (Patel *et al.,* 2011).The range of the soil's essential zinc content is 0.38 to 2 mg kg^{-1}. Due to the exchangeable Zn sites in the soil solid matrix that are provided and the improved cation exchange capacity of soil by organic matter, plants can also access Zn that is bound to organic matter (Khoshgoftarmanesh*et al.,* 2018). For many crop plants, zinc belongs among the most crucial nutrients. Zn is crucial for the development of the human immune system and brain function, as well as for enzymatic processes and metabolic processes in plant systems(Dhaliwal*et al.*, 2022).In plants, zinc plays a crucial role as a structural component or regulatory cofactor of a wide range of enzymes and proteins in many important biochemical pathways(Alloway, B. J., 2009).Due to the poor availability of Zn in Indian soils, rice with low Zn content is produced. Foliar Zn application to wheat and rice has attracted a lot of interest recently. In order to better understand how Zn application can affect growth, yield qualities, Zn concentration, uptake, and use efficiency in Basmati rice, which is the most popular cereal in India and many other nations around the world, the current study was carried out. Lowland rice from Brazil and India has been found to be deficient in zinc (Fageria*et al.*, 2011).The foliar application of zinc fertilizer improves zinc concentration in grain. In particular studies, soil and foliar application of Zn improve crop yield (Kumar *et al*., 2023[a]).

Compost alone and in conjunction with chemical fertilizer at the same amount decreased the pH of the soil, increased electrical conductivity, and improved the soil's availability of phosphorus, water-soluble potassium, and organic matter (Kumar*et al*., 2023). While addition of organic material to the soil such as farm yard manure helps in maintaining soil fertility and productivity (Kumar *et al*., 2023).For greater yield and healthy soil, organic manures, crop wastes, and vermicompost are required in addition to inorganic fertilizers (Pandey *et al*., 2023[a]).

Soil biological activity assessment is also necessary to ensure the long-term viability of soil ecology. Soil is a home to a rich microbial ecology that includes microscopic bacteria and fungi, micro fauna (nematodes and protozoans), mesofauna, and macro fauna (Pandey *et al*., 2023).

Materials and methods

Site Description

The field experiment was conducted during Kharif season 2022 at Student's Instructional farm of Acharya Narendra Deva University of Agriculture and Technology Kumarganj, Ayodhya Uttar Pradesh, India, on the left side of Ayodhya-Raibareilly road at a distance of 43 km away from Ayodhya district headquarter.

Variety Description

Rice NDR- 2065 variety was taken for experiment which has been released in year 2011 from Crop Research Station, Masodha, Acharya Narendra Deva University of Agriculture and Technology Kumarganj, Ayodhya (UP)-224229 by Department of Genetics and Plant Breeding. It is an early maturity variety (120-125 days.) Yield varies from 50-55 q ha^{-1} with good soil fertility and agronomical practices.The experiment was laid out in Randomized Block Design (RBD) with three replications.To evaluate the treatment effect, various observation were recorded. The amount of farm yard manure (FYM) was firstly calculated on the basis of their actual nitrogen content. The calculated quantity of FYM were applied in slightly moist soil about one week before transplanting of nursery. The required amount of fertilizers were applied as per treatment, N_2 through Urea, P_2O_5 through DAP, K_2O through MOP and Zn through $ZnSo_4$ (monohydrate). Half dose of nitrogen and full dose of phosphorus, potassium and zinc sulphate applied as basal application at the time of field preparation. Rest dose of nitrogen applied as top dressing in two split doses 25 DAT and 45 DAT, respectively.

Soil Sampling and Analysis

Soil sampling done by Auger randomly from each replicated plot after, harvesting of rice crop and collect the sample in polythene bag plot wise. Samples are brought to Soil Science Lab ANDUAT Kumarganj Ayodhya for analysis. Soil texture, Bulk density, Soil pH, Electrical conductivity, Organic carbon, available N, P, K and Zn determined from the processed samples for each treatment (in triplicate) as per the standard methods (Prasad *et al*., 2006). Physico-chemical biological study of soil before and after harvesting of rice crop. Soil Biological and biochemical activity in terms of dehydrogenase enzyme, microbial biomass carbon and total microbial count was measured after the harvesting of crop. Random soil samples done individual plot wise from experimental field with 0-15 cm soil depth were collected by core sampler. The soil samples packed with air tight polythene bag and air dried samples passed through 2 mm mesh screen sieves.

Results and Discussion

Effect of Graded Fertility Levels and Zinc Application of Organic Manure on Physiochemical Properties of Soil

Soil pH

The effect of various treatment combinations on soil pH is presented in Table 1. There were non significantly affected by various treatment combinations. The highest value of pH (8.35) was recorded with T_1 control and lowest value (8.01) was recorded with T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application.

However soil pH maintained or slight decreased to the initial value might be due to the formation of organic acids during the decomposition of organic manure and crop residues. Similar results corroborated with Sharma *et al.* (2013), Yaduvanshi (2001), Lamichhane *et al.* (2022), Parewa*et al.* (2014). and Pandey *et al*., (2023).

Electrical Conductivity (dS m^{-1}):

The data regarding effect of various treatment combinations on electrical conductivity remained non-significant in between the treatments but there is slightly decrease from initial (0.35 dSm^{-1}) to harvest (0.28 dSm^{-1}). However, the lowest EC (0.27 dS m^{-1}) at harvest recorded with T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application and highest EC (0.36 dSm^{-1}) was recorded at harvest with T_1 control in rice have been presented in Table 1.

The sudden decrease of electrical conductivity in organic applied treatment may be due to the buffering action of organic matter, which decreases the solution concentration of ionic species, decreasing the EC. In FYM, the significant increase in microbial activity leads to the uptake of soluble salts by microorganisms for the growth of microbial cell mass leads to less EC when compared to vermicompost. This similar results was reported by Nasrin *et al.* (2019).

Organic carbon (g kg^{-1}):

The data on organic carbon content in soil influenced by various treatment combination is presented in Table 1.

The maximum organic carbon (3.9 g kg^{-1}) observed with T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application, it was at par with T_9, T_3, T_6, $T_{5,}$ T_7 and T_8 and the minimum organic carbon was recorded with T_1 control (3.3 g kg^{-1}) at harvest.

The increased organic carbon content due to use of enriched FYM can be attributed to higher contribution of biomass to the soil in the form of root, crop stubbles and residues but also to better root growth and plant residue addition by the growing crop at harvesting. It is an important source of soil organic matter and nutrients which after decomposition by the microorganisms becomes available to the plants. These results are in line with findings of Abraham and Lal (2004), Thakur *et al*. (2011), Singh *et al*. (2012) and Regar and Yadav (2019).

Bulk Density (Mg m^{-3})

Data with respect to bulk density of soil were affected by various treatment combinations have been presented in Table2.

The minimum bulk density (1.35 Mg m^{-3}) was recorded with T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application and higher value (1.39 Mg m^{-3}) was recorded with T_1 control. The difference was not up to the level of significance in this regard. Also, the application of FYM reduces the bulk density of soil.

The bulk density of soil decreased significantly with incorporation of FYM was might be due to increase in organic content in the soil. These results are corroborated with the findings of Parewa*et al*. (2014), Prakash *et al*. (2002) and Dadhich *et al*. (2011).

Table 1. Effect of Graded Fertility Levels and Zinc Application of Organic Manure on Physiochemical Properties of Soil

Treatments	**pH (1:2.5)**	**EC (dS m^{-1})**	**OC (g kg^{-1})**
T_1-Control	8.35	0.36	3.3
T_2-100% RDF (150, 60, 40 N, P_2O_5, K_2O kg ha^{-1})	8.32	0.35	3.5
T_3-100% RDF + 25 kg $ZnSO_4$ ha^{-1} Soil application	8.20	0.31	3.7
T_4-100% RDF + 0.5% $ZnSO_4$ spray at tillering stage	8.30	0.34	3.5
T_5-100% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage	8.25	0.32	3.6
T_6-75% RDF + 25 kg $ZnSO_4$ ha^{-1} Soil application	8.18	0.31	3.7
T_7-75% RDF + 0.5% $ZnSO_4$ spray at tillering stage	8.28	0.33	3.6
T_8-75% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage	8.23	0.32	3.6
T_9-75% RDF + 25% FYM-N +0.5% $ZnSO_4$ spray at tillering stage + PI stage	8.02	0.29	3.8
T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application	8.01	0.28	3.9
SEm±	0.10	0.005	0.01
CD (P=0.05)	NS	NS	0.03

Table 2.Effect of Graded Fertility Levels and Zinc Application of Organic Manureon bulk density of soil after harvest of Rice

Treatments	**Bulk density (Mg m^{-3})**
T_1-Control	1.39
T_2-100% RDF (150, 60, 40 N, P_2O_5, K_2O kg ha^{-1})	1.38
T_3-100% RDF + 25 kg $ZnSO_4$ ha^{-1} Soil application	1.38
T_4-100% RDF + 0.5% $ZnSO_4$ spray at tillering stage	1.38
T_5-100% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage	1.38
T_6-75% RDF + 25 kg $ZnSO_4$ ha^{-1} Soil application	1.37
T_7-75% RDF + 0.5% $ZnSO_4$ spray at tillering stage	1.37
T_8-75% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage	1.37
T_9-75% RDF + 25% FYM-N +0.5% $ZnSO_4$ spray at tillering stage + PI stage	1.35
T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application	1.35
SEm±	0.01
CD (P=0.05)	NS

Available nitrogen (kg ha^{-1})

Data with respect of available nitrogen in soil after harvest of crop as affected by various treatment combinations are presented in Table 3 and Fig. 1.

Data clearly showed that available nitrogen was influenced significantly by various treatment combination. The maximum available nitrogen (213.15 kg ha^{-1}) was obtained with T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application which was significantly superior with T_1, T_2, T_3, T_4, T_7 and T_8 and statistically at par with T_9, T_6, and T_5. The lowest available nitrogen (196.11 kg ha^{-1}) observed in T_1 control.

A significant increase in available nitrogen due to combined application of NPK with zinc which form synergistic relationship and helps in increased available nitrogen. The available nitrogen in soil was higher at panicle initiation stage of crop and declined at later stage. Similar result was also observed by Kumar *et al.* (2017).

Available phosphorous (kg ha^{-1})

Data with respect to available phosphorus as affected by different treatment combinations is presented in Table 3 and Fig.1.

A critical examination of the data revealed that various treatment combinations had significant effect on increases of available phosphorus. The maximum available phosphorus (15.60 kg ha^{-1}) was recorded with T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application which was significantly superior over rest treatment. The minimum available phosphorus (12.15 kg ha^{-1}) recorded with T_1 control.

The improvement in the soil available phosphorus due to FYM addition could be attributed to many factors, such as the addition of phosphorus through FYM and retardation of soil P fixation by organic anions formed during FYM decomposition. Similar views also expressed by **Reagar and Yadav (2019)**, **Chand (2007)**, **Dadhich *et al*. (2011)** and **Singh *et al.* (2012)**.

Available potassium (kg ha^{-1})

Data with respect to available potassium as affected by different treatments is presented in Table 3 and Fig.1.

Potassium content among soils significantly affected by various treatment combinations. The maximum available potassium (275.15 kg ha^{-1}) was recorded with T_{10}-75% RDF + 25%

FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application which was statistically at par with T_9 and T_3. The minimum available potassium (258.85 kg ha^{-1}) was recorded with T_1 control.

The increase in release rate of potassium on application of organic and inorganic fertilizers resulted in larger decline of K in reserve pool of the soil. Similar result were also reported by **Kumar *et al.* (2017)** and **Tiwari *et al*., (2020).**

Available Zinc (ppm)

Data with respect to available zinc in soil after harvest of crop as affected by various treatment combinations presented in Table 3 and Fig.1.

The data revealed that the highest available zinc (0.71 ppm) was recorded with T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application which was significantly superior over rest treatments. Minimum available zinc (0.49 ppm) was recorded in T_1 control.

Available zinc in soil may also increase due to application of phosphorus along with Zn enriched FYM which reduce fixation of chelated mineral Zn and also make available native Zn through solubilization. Similar results revealed by **Reagar and Yadav (2019)**.

Table 3. Effect of Graded Fertility Levels and Zinc Application of Organic Manure on availability of nutrients in soil after

Treatments	**Available Nutrients (kg ha^{-1})**			
	N	**P**	**K**	**Zn(ppm)**
T_1-Control	196.11	12.18	258.85	0.49
T_2-100% RDF (150, 60, 40 N, P_2O_5, K_2O kg ha^{-1})	203.50	13.75	264.70	0.52
T_3-100% RDF + 25 kg $ZnSO_4$ ha^{-1} Soil application	210.35	14.80	272.10	0.61
T_4-100% RDF + 0.5% $ZnSO_4$ spray at tillering stage	207.01	14.10	268.01	0.54
T_5-100% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage	207.95	14.30	270.02	0.58
T_6-75% RDF + 25 kg $ZnSO_4$ ha^{-1} Soil application	209.12	14.60	271.03	0.64
T_7-75% RDF + 0.5% $ZnSO_4$ spray at tillering stage	204.72	13.70	265.75	0.55
T_8-75% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage	205.70	13.85	266.80	0.60
T_9-75% RDF + 25% FYM-N +0.5% $ZnSO_4$ spray at tillering stage + PI stage	212.10	15.11	273.70	0.67
T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application	213.15	15.60	275.15	0.71
SEm±	1.86	0.13	1.15	0.01
CD (P=0.05)	5.54	0.39	3.42	0.03

Harvest of the crop.

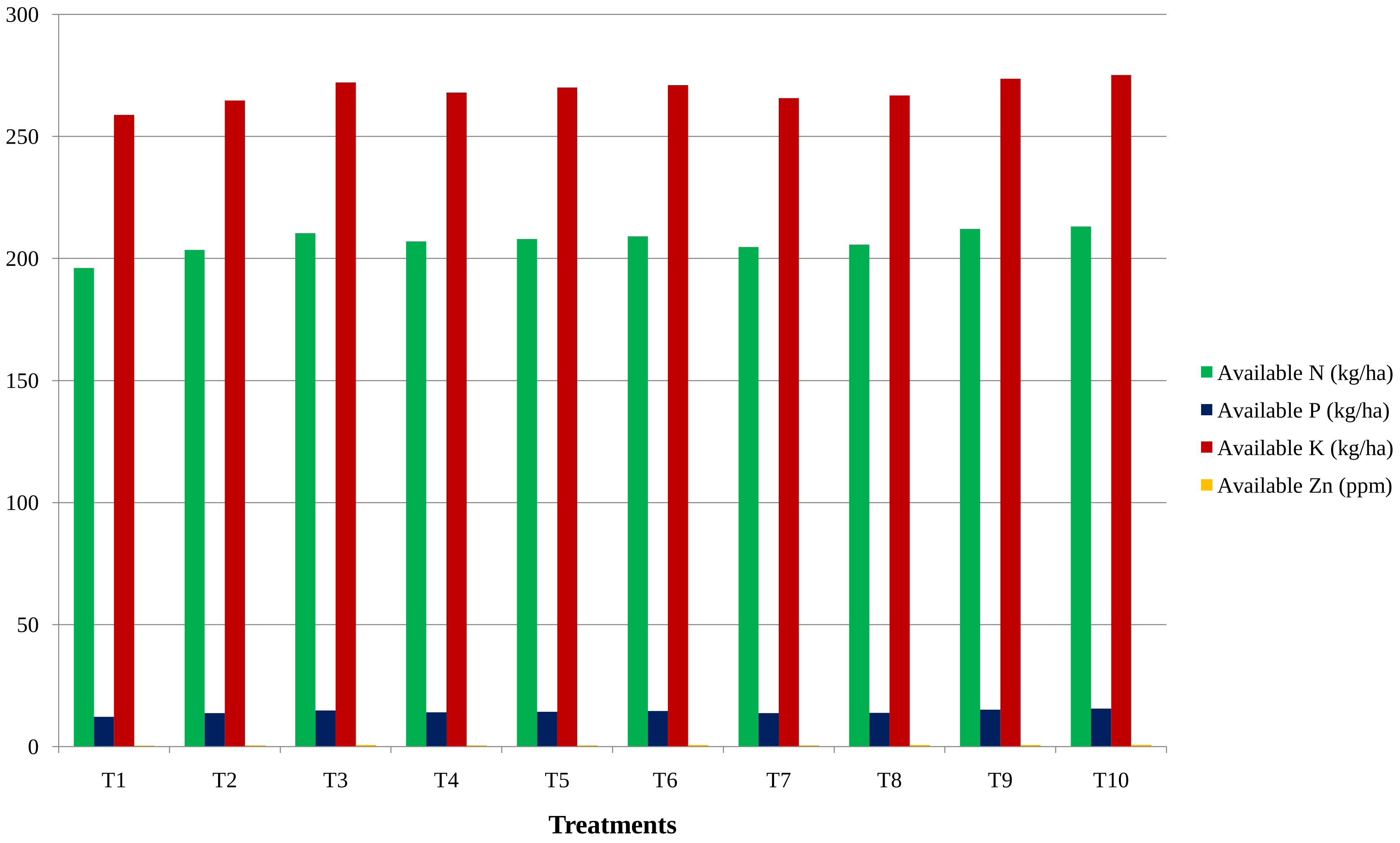

Fig. 1. Effect of Graded Fertility Levels and Zinc Application of Organic Manure on availability of nutrients in soil after harvest

Effect of Graded Fertility Levels and Zinc Application of Organic Manure on Biological and bio-chemical properties of soil after harvest of rice

Microbial biomass Carbon (µg MBCg^{-1} soil)

Data pertaining to soil microbial biomass carbon as affected by various treatment combinations calculated in terms of Microbial biomass carbon (MBC) expressed as µg microbial biomass carbon g^{-1} soil per hour of incubation, are presented in Table 4. and Fig.3.

Close examination of data revealed that different applied treatments significantly influenced the 'MBC' activity. The maximum activity (177.3 µg MBC g^{-1} soil) was observed under T_{10} followed by T_9. Minimum MBC activity (166.3 µg MBC g^{-1} soil) was associated with T_1 control.

Microbial biomass carbon increased with increase in doses of inorganic fertilizers may be due to firstly to increase in microbial population and secondly to formation of root exudates, mucigel soughed off cells and underground roots of previous cut crops, which also play an important role in increasing SMBC. The higher microbial biomass in FYM might be due to higher below ground plant residues as well as added FYM. Similar findings results with **Parewa*et al*. (2014)**, **Gogoi *et al*. (2010)**.

Soil Dehydrogenase (µg TPF g soil^{-1} day^{-1})

Dehydrogenase enzyme activity is one of the vital soil characteristics because it reflects the bioavailable levels of nitrogen and activity of microbial population in soil. Data with respect to activity of soil dehydrogenase activity of rice as affected by various treatment combinations which are presented in Table 4. and Fig. 3.

Data revealed that the soil dehydrogenases enzyme were significantly affected by various treatment combinations. The maximum activity of soil dehydrogenase (136.9 µg TPF g soil^{-1} day^{-1}) was observed with T_{10} which was statistically at par with T_9 and among rest treatments are superior. Minimum total activity (91.1 µg TPF g soil^{-1} day^{-1}) of soil dehydrogenases was associated with T_1 control.

Dehydrogenase enzyme activity acts as measure of comprehensive microbial activity in soil. Greater dehydrogenase enzyme activity was noticed in integrated nutrient management treatments because degradation of added organic material supposed to provide intra and extra cellular enzymes that eventually increase microbial activity in soil. This results finds conformity with the discussions of **Nandy *et al*. (2022)**.

Table 4. Effect of graded fertility levels and zinc application with and without FYM on biological and bio-chemical properties of soil after harvest of rice

Treatments	Microbial Biomass Carbon(µg MBC g^{-1}soil)	Soil Dehydrogenase(µg TPF g $soil^{-1}day^{-1}$)
T_1-Control	166.3	91.1
T_2-100% RDF (150, 60, 40 N, P_2O_5, K_2O kg ha^{-1})	168.1	93.2
T_3-100% RDF + 25 kg $ZnSO_4$ ha^{-1} Soil application	171.2	95.1
T_4-100% RDF + 0.5% $ZnSO_4$ spray at tillering stage	169.3	92.7
T_5-100% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage	170.1	93.8
T_6-75% RDF + 25 kg $ZnSO_4$ ha^{-1} Soil application	174.7	114.2
T_7-75% RDF + 0.5% $ZnSO_4$ spray at tillering stage	172.2	112.9
T_8-75% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage	173.8	113.3
T_9-75% RDF + 25% FYM-N +0.5% $ZnSO_4$ spray at tillering stage + PI stage	176.9	136.7
T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application	177.3	136.9
SEm±	0.84	0.87
CD (P=0.05)	2.49	2.58

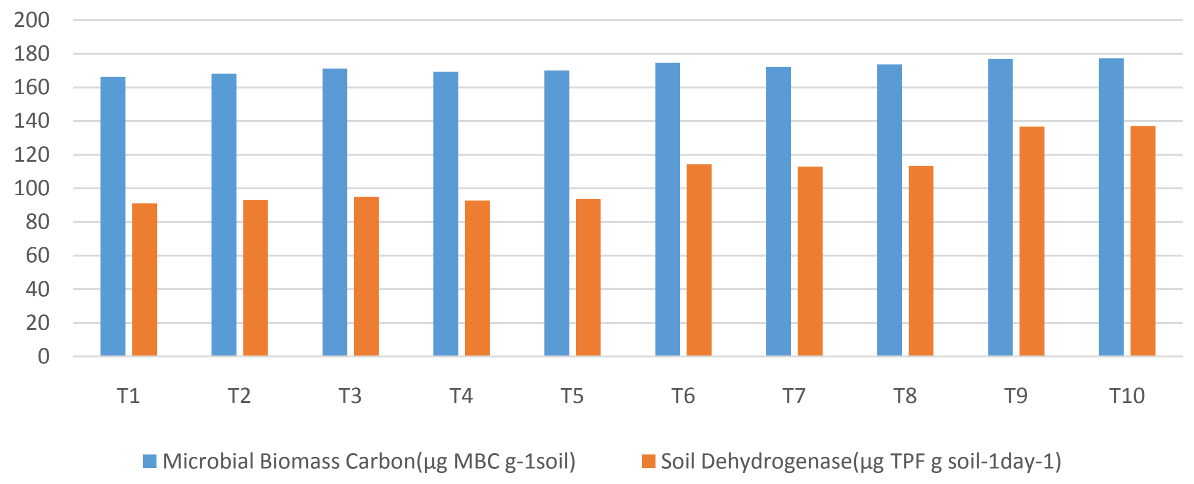

Fig.2. Effect of graded fertility levels and zinc application with and without FYM on biological and bio-chemical properties of soil after harvest of rice

Soil Microbial population

Data with respect to the total number of soil microbial population (Bacteria, Fungi and Actinomycetes) of rice as affected by different treatment combinations are presented in Table 5.

Data revealed that different organic manure and inorganic fertilizers significantly influenced the total number of Soil Bacteria, Fungi and Actinomycetes in rice. The maximum total number of soil bacteria (11.4×10^{6}cfu g^{-1}soil), Fungi (7.3×10^{3}sfu g^{-1} soil) and actinomycetes (8.6×10^{4}cfu g^{-1} soil) were observed with the application T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application followed by T_9. The minimum total number of Soil Bacteria (5.2×10^{6}cfu g^{-1} soil), Fungi (5.9×10^{3} sfu g^{-1} soil) and Actinomycetes (5.9×10^{4}cfu g^{-1} soil) were associated with T_1 control.

A profound increase in microbial population was observed in organic manure addition with inorganic fertilizer and foliar spray of zinc applied plots as compared to only chemical fertilizer application because organic matter serves as a source of the nourishment and also as a substances for decomposition and mineralization of nutrients which creates a favorable condition for growth of microbes in the soil. Similar findings were also observed by Nandy *et al*. (2022), Bahadur *et al*. (2012), Kumari *et al*. (2017), Kumar *et al*. (2017) and Raliya and Tarafdar (2013).

Table 5.Effect of Graded Fertility Levels and Zinc Application of Organic Manureon Soil Microbial Population after harvest of rice

Treatments	**Bacteria ($\times 10^6$ cfu)**	**Actinomycetes ($\times 10^4$ cfu)**	**Fungi ($\times 10^3$sfu)**
T_1-Control	5.2	5.9	5.9
T_2-100% RDF (150, 60, 40 N, P_2O_5, K_2O kg ha^{-1})	6.3	6.7	6.1
T_3-100% RDF + 25 kg $ZnSO_4$ ha^{-1} Soil application	8.4	7.2	6.4
T_4-100% RDF + 0.5% $ZnSO_4$ spray at tillering stage	6.9	6.9	6.0
T_5-100% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage	7.7	7.1	6.3
T_6-75% RDF + 25 kg $ZnSO_4$ ha^{-1} Soil application	9.3	7.9	6.9
T_7-75% RDF + 0.5% $ZnSO_4$ spray at tillering stage	8.2	7.1	6.5
T_8-75% RDF + 0.5% $ZnSO_4$ spray at tillering stage + PI stage	9.0	7.8	6.7
T_9-75% RDF + 25% FYM-N +0.5% $ZnSO_4$ spray at tillering stage + PI stage	10.9	8.3	7.1
T_{10}-75% RDF + 25% FYM-N +25 kg $ZnSO_4$ ha^{-1} Soil application	11.4	8.6	7.3
SEm±	0.10	0.11	0.09
CD (P=0.05)	0.29	0.32	0.26

CONCLUSION

After the rice crop has been harvested, the application of 75% RDF + 25% FYM-N + 25 kg $ZnSO_4$ ha^{-1} to the soil has no appreciable impact on its bulk density, pH, or electrical conductivity. Organic carbon, Available N, P, K, and Zn in the soil have all been considerably impacted by the application of75% RDF + 25% FYM-N + 25 kg $ZnSO_4$ ha^{-1}. Carbon derived from microbial biomass, soil dehydrogenase, and overall soil microbial population.

References

Abraham, T., and Lal, R. B. (2004). Effect of integrated nutrient management on productivity of wheat (*Triticum aestivum*L.) and soil fertility in a legume based cropping system. *Indian J. Agric. Res.*, *38*(3), 178-183.

Alloway, B.J. (2009). Soil factors associated with zinc deficiency in crops and humans. *Environmental geochemistry and health*, **31** (5), 537-548.

Bahadur, L., Tiwari, D. D., Mishra, J., and Gupta, B. R. (2012). Effect of integrated nutrient management on yield, microbial population and changes in soil properties under rice-wheat cropping system in sodic soil. *J. Indian Soc. Soil Sci.*, *60*(4), 326-329.

Chand, S., Pande, P., Prasad, A., Anwar, M., & Dhar Patra, D. (2007). Influence of Integrated Supply of Vermicompost and Zinc-Eniched Compost with Two Graded Levels of Iron and Zinc on the Productivity of Geranium. *Communications in Soil Science and Plant Analysis*, *38*(19-20), 2581-2599.

Dadhich, S. K., Pandey, A. K., Prasanna, R., Nain, L., and Kaushik, B. D. (2012). Optimizing crop residue-based composts for enhancing soil fertility and crop yield of rice. *Indian J. Agric. Sci.*, *82*(1), 85.

Dhaliwal, S. S., Sharma, V., Shukla, A. K., Kaur, J., Verma, V., Kaur, M., ... & Hossain, A. (2022). Interactive effects of molybdenum, zinc and iron on the grain yield, quality, and nodulation of cowpea (*Vigna unguiculata* (L.) Walp.) In North-Western India. Molecules, **27** (11), 3622.

Fageria, N. K., Moreira, A., & Coelho, A. M. (2011). Yield and yield components of upland rice as influenced by nitrogen sources. *Journal of Plant nutrition*, **34**(3), 361-370.

Gogoi, B., Barua, N. G., and Baruah, T. C. (2010). Effect of integrated supply of nutrients on soil microbial biomass carbon in an Inceptisol of Assam. *J. Indian Soc. Soil Sci.*, *58*(2), 241-244.

Khoshgoftarmanesh, A. H., Afyuni, M., Norouzi, M., Ghiasi, S., and Schulin, R. (2018). Fractionation and bioavailability of zinc (Zn) in the rhizosphere of two wheat cultivars with different Zn deficiency tolerance. *Geoderma*, *309*, 1-6.

Kumar, D., Shahi, U. P., Shekhar, C., Kumar, A., Pal, S., & Kumar, S. (2023)^{a}. Effect of Soil and Foliar Application of Zn and Fe on Nutrient Status of Hybrid Maize (*Zea mays* L.). *Int. J. Plant Soil Sci*, **35**(19), 1110-1119.

Kumar, M. M., Subbarayappa, C. T., and Ramamurthy, V. (2017). Effect of graded levels of zinc and boron on growth, yield and chemical properties of soils under Paddy. *Int. J. Curr. Microbiol. App. Sci*, *6*(10), 1185-1196.

Kumar, S., Agrawal, S., Jilani, N., Kole, P., Kaur, G., Mishra, A., ... & Tiwari, H. (2023). Effect of integrated nutrient management practices on growth and productivity of rice: A review.*The Pharma Innovation Journal*; **12** (5): 2648-2662.

Kumar, S., Kumar, S., Kumar, R., Pathak, D., Kumar, D., Kumar, A., ... & Tiwari, H. (2023). Assessment of Physico-chemical Properties of Soil as Influenced by Different Moisture Regimes and Nitrogen Sources in Wheat Crop. *Int. J. Plant Soil Sci*, **35** (19), 765-772.

Kumari, J. A., Rao, P. C., Padmaja, G., and Madhavi, M. (2017). Effect of Physico-chemical properties on soil enzyme urease activity in some soils of Ranga reddy district of Telangana State, India. *Int. J. Curr. Microbiol. Appl. Sci*, *6*, 1708-1714.

Lamichhane, S., Khanal, B. R., Jaishi, A., Bhatta, S., Gautam, R., and Shrestha, J. (2022). Effect of Integrated Use of Farmyard Manure and Chemical Fertilizers on Soil Properties and Productivity of Rice in Chitwan. *Agron. J. Nepal*, *6*, 200-212.

Mishra, P., & Dash, D. (2014). Rejuvenation of biofertilizers for sustainable agriculture and economic development. *Consilience*, (11), 41-61.

Muthayya, S., Sugimoto, J. D., Montgomery, S., & Maberly, G. F. (2014). An overview of global rice production, supply, trade, and consumption. *Annals of the New York Academy of Sciences*, **1324**(1), 7-14.

Nandy, P., Das, S. K., and Tarafdar, J. C. (2022). Effect of Integrated Nutrient Management and Foliar Spray of Zinc in Nanoform on Rice Crop Nutrition, Productivity and Soil Chemical and Biological Properties in Inceptisols. *J. Soil Sci. Plant Nutr.*, 1-16.

Nasrin, A., Khanom, S., & Hossain, S. A. (2019). Effects of vermicompost and compost on soil properties and growth and yield of Kalmi (Ipomoea aquatica Forsk.) in mixed soil. *Dhaka University Journal of Biological Sciences*, *28*(1), 121-129.

Pandey, P. R., Singh, S. P., Dhyani, B. P., Kumar, Y., Singh, A., Kumar, A., & Kumar, S. (2023)^{a}. Impact of Different Nutrient Management Practices on the Nutrient Dynamics of Wheat Crop in Western Uttar Pradesh, India. *Int. J. Plant Soil Sci*, **35**(19), 560-571.

Pandey, P. R., Singh, S., Dubey, S., Kumar, S., Singh, V., Mishra, H., ... & Tiwari, H. (2023). Assessment of Soil Microbial Status under Different Land Use System at Various Depth. *International Journal of Environment and Climate Change*, **13**(10), 603-615.

Pandey, P. R., Zaidi, S. F. A., Kumar, S., Pathak, D., Shukla, G., & Pal, R. (2023). Depth Wise Studies of Physico-Chemical Properties of Soil under Different Land Use System at Eastern UP, India. *International Journal of Plant & Soil Science*, **35**(18), 762-772.

Parewa, H. P., Yadav, J., and Rakshit, A. (2014). Effect of fertilizer levels, FYM and bioinoculants on soil properties in inceptisol of Varanasi, Uttar Pradesh, India. *Int. j. agric. environ. biotechnol.*, *7*(3), 517-525.

Patel, M. M., Patel, I. C., Patel, R. I., & Acharya, S. (2011). Effect of zinc and iron on yield and yield attributes of rainfed cowpea (*Vigna unguiculata* L. Walp). *Annals of Arid Zone*, **50**(1), 17-19.

Prakash, Y. S., Bhadoria, P. B. S., & Rakshit, A. (2002). Comparative efficacy of organic manures on the changes in soil properties and nutrient availability in an alfisol. *Journal of the Indian Society of Soil Science*, *50*(2), 219-221.

Raliya, R., & Tarafdar, J. C. (2013). ZnO nanoparticle biosynthesis and its effect on phosphorous-mobilizing enzyme secretion and gum contents in Clusterbean (Cyamopsis tetragonoloba L.). *Agricultural Research*, *2*, 48-57.

Regar, K. L., and Yadav, J. (2019). Effect of enriched FYM and P2O5 levels on physio-chemical properties of soil after harvesting of rice. *IJCS*, *7*(1), 2520-2526.

Sharma, Y. K., Sharma, A., and Sharma, S. K. (2013). An appraisal of physico-chemical characteristics and soil fertility status of forest and rice land use systems in Mokokchung district of Nagaland. *J. Indian Soc. Soil Sci.*, *61*(1), 38-43.

Singh, A., Singh, V. K., Chandra, R., and Srivastava, P. C. (2012). Effect of integrated nutrient management on pigeon pea-based intercropping system and soil properties in Mollisols of the Tarai region. *J. Indian Soc. Soil Sci., 60*(1), 38-44.

Thakur, R., Sawarkar, S. D., Vaishya, U. K., and Singh, M. (2011). Impact of continuous use of inorganic fertilizers and organic manure on soil properties and productivity under soybean-wheat intensive cropping of a Vertisol. *J. Indian Soc. Soil Sci*., *59*(1), 74-81.

Tiwari, H., Singh, A. K., Pandey, S. R., & Tiwari, A. (2020). Effect of Integrated nutrient management practices on nutrient content and uptake by rice (*Oryza sativa* L.). *Journal of Pharmacognosy and Phytochemistry*, **9**(6), 2131-2134.

Tripathi B N and Kumar R., (2013). Effect of Zinc and Sulphur Levels on Rice in Partially Reclaimed Typic Natrustalfs Sodic Soil. *Ann. plant soil res.* 15(1): 27-30.

Yaduvanshi, N. P. S. (2001). Effect of five years of rice-wheat cropping and NPK fertilizer use with and without organic and green manures on soil properties and crop yields in a reclaimed sodic soil. *Journal of the Indian Society of Soil Science*, *49*(4), 714-719.