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Response of Integrated Nutrient Management on Physico-chemical Properties of Soil of Rice in Inceptisols of Prayagraj, India

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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ABSTRACT

The experiment for the two consecutive years, beginning from kharif season pooled data of two years 2023 and 2024 at Research Farm, Department of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj district of Uttar Pradesh. The maximum temperature of the location reaches up to 460C - 480C and minimum temperature is 40C - 5 0C. The relative humidity ranged between 20 to 94 percent. The average rainfall in this area is around 1100 mm annually. The experiment was laid down in Randomized Block Design (RBD) with sixteen treatments of rice which replicated thrice. The INM treatments in the rice were included T_1:(Control), T_2:RDF @ 100%, T_3:RDF @ 100%+ @ 50% Zn SA, T_4:RDF @ 100%+ @ 100% Zn SA, T_5:RDF @ 50% + @ 0.5 % Zn foliar application, T_6:RDF @ 100 %+ @ 0.5 % Zn foliar application, T_7:RDF @100% + @ FYM 100%, T_8: RDF @ 50% +@ 50% FYM + @ 50%Zn SA, T_9: RDF @ 100% + @ 100% FYM + @ 100% Zn SA, T_{10}: RDF @ 50% + @ 50% FYM + @ 0.5% Zn foliar application, T_{11}: RDF@100 % +@100 % FYM + @ 0.5% Zn foliar application, T_{12}: RDF @100% +@100% Vermicompost, T_{13}: RDF @50% + @50% Vermicompost + @ 50% Zn SA, T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA, T_{15}: RDF @ 50%+ @50% Vermicompost + @ 0.5% Zn foliar application and T_{16}: RDF @100% + @100% Vermicompost + @ 0.5% Zn foliar application. ZnSO4 soil application @ 25 kg ha-1 as basal dose, foliar application of 0.5 % Zn solution at different days after transplanting. The treatment plot size is 2x2m. The soil sample was analyzed for bulk density, particle density, %pore space, water holding capacity (%), pH, EC, %Organic carbon, Available N,P, K and Zinc. The results revealed that the application of T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA non-significantly minimum bulk density (1.078 and 1.097), pH (6.82 and 6.81) and EC (0.214 and 0.216 dS m^{-1}) after harvest of rice at 0-15 and 15-30 cm depth in pooled data of two years 2023 and 2024 and significantly maximum particle density (2.64 and 2.66), %pore space (49.51 and 49.50), water holding capacity (52.22 and 52.00%), %Organic carbon (0.552 and 0.548) after harvest of rice at 0-15 and 15-30 cm depth in pooled data of two years 2023 and 2024. It was observed that the treatment comprising of T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA registered higher values of available nitrogen (250.173 and 232.852 kg ha^{-1}), available phosphorus (35.397 and 30.114 kg ha^{-1}), available potassium (220.790 and 215.877) and Zinc (0.582 and 0.572 mg kg^{-1}) after harvest of rice at 0-15 and 15-30 cm depth in pooled data of two year 2023 and 2024.

Keywords: INM; Physico-chemical analysis; soil; NPK and Zinc

1. INTRODUCTION

"Inceptisols are that soils which have undergone modifications of the parent material by soil-forming processes that are sufficiently great to distinguish the soils from Entisols, but not intense enough to form the kinds of horizons required for classification into other soil orders. Most Inceptisols have cambic horizons and are eluvial soils" (Smith 1965). "The Inceptisols are the prime lands of the state with intensive agriculture being practised on these soils. Though the majority of the Inceptisols in the state are coarse to medium textured soils, however, some are fine-textured Inceptisols, are found in alluvial plains in the old flood plain areas. These soils are very fine in texture and have strong angular blocky structure with pressure faces and slickensides. Due to the presence of vertical cracks up to a depth of 30 cm and the ustic moisture regime, these soils are classified as Vertic Ustochrepts. The fine textured Inceptisols have not been shown to be chemically constrained for crop productivity" (Singh et al., 2019). "Nutrient management by integrating organic sources of nutrients along with inorganic fertilizers may play an important role in improving and sustaining rice productivity, moreover, chemical fertilizers will play a major role as these contribute about 50% to the increase in food grain production for ever increasing population of our country" (Mahajan & Gupta, 2009). Organic sources of plant nutrients offer the twin benefits of increasing organic matter content and improving the physical and chemical qualities of soil, in addition to providing nutrients to crops. Integrated nutrient management is one of the most crucial techniques for increasing resource efficiency and yielding crops at lower cost. In order to maintain soil fertility and crop productivity, integrated nutrient management (INM) refers to the coordinated use of all available nutrient sources, including organic, inorganic and bio fertilizers, based on economic considerations. "In addition to increasing crop productivity and profitability, the integrated application of both organic and inorganic sources of nutrients contributes to the preservation of soil fertility. Compared to using each component separately, integrated nutrition management has shown to have a longer-term positive impact" (Palaniappan and Annadurai, 2007). If applied consistently, it can enhance soil health and rice yield over time (Nanda et al., 2016); it can also prevent micronutrient mining (Singh et al., 2019). However, "an uneven application of fertilizer might disrupt the availability of nutrients, which lowers soil production" (Singh et al., 2019). "Applying chemical fertilizers and organic manures together can effectively address issues with declining crop output and soil health" (Singh et al., 2019; Upadhyay and Viswakarma 2014). "Rice is one of the three largest important food crops in the world (World Food and Agriculture – Statistical Yearbook, 2022), which plays a vital role in the social economy, and consistent rice production is required to confirm future food security" (Alexandratos & Bruinsma, 2012). "Rice (*Oryza sativa*) stands as one of the paramount staple food crops globally, belonging to the Poaceae family and originating in South East Asia. Its cultivation spans approximately 165.22 million hectares worldwide, yielding 509.29 million tonnes in the 2022-23 period" (Anonymous, 2022). In India, rice cultivation covers 45 million hectares, yielding 127.93 million tonnes with a productivity of 23.9 q ha-1 in 2021-22 (Anonymous, 2021).

2. MATERIALS AND METHODS

The experiment conducted over two consecutive years, beginning from kharif season pooled data of two years 2023 and 2024 at Research Farm, Department of Soil Science and Agricultural Chemistry, Sam Higginbottom University of Agriculture, Technology and Sciences, Prayagraj district of Uttar Pradesh. The maximum temperature of the location reaches up to 460C - 480C and minimum temperature is 40C - 5 0C. The relative humidity ranged between 20 to 94 percent. The average rainfall in this area is around 1100 mm annually. The experiment was laid down in Randomized Block Design (RBD) with sixteen treatments of rice which replicated thrice. The INM treatments in the rice were included T_1:(Control), T_2:RDF @ 100%, T_3:RDF @ 100%+ @ 50% Zn SA, T_4:RDF @ 100%+ @ 100% Zn SA, T_5:RDF @ 50% + @ 0.5 % Zn foliar application, T_6:RDF @ 100 %+ @ 0.5 % Zn foliar application, T_7:RDF @100% + @ FYM 100%, T_8: RDF @ 50% +@ 50% FYM + @ 50%Zn SA, T_9: RDF @ 100% + @ 100% FYM + @ 100% Zn SA, T_{10}: RDF @ 50% + @ 50% FYM + @ 0.5% Zn foliar application, T_{11}: RDF@100 % +@100 % FYM + @ 0.5% Zn foliar application, T_{12}: RDF @100% +@100% Vermicompost, T_{13}: RDF @50% + @50% Vermicompost + @ 50% Zn SA, T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA, T_{15}: RDF @ 50%+ @50% Vermicompost + @ 0.5% Zn foliar application and T_{16}: RDF @100% + @100% Vermicompost + @ 0.5% Zn foliar application. ZnSO4 soil application @ 25 kg ha-1 as basal dose, foliar application of 0.5 % Zn solution at different days after transplanting. The treatment plot size is 2x2m. The soil of the experimental plot is alluvial and falls into the order Inceptisol. The soil samples were collected randomly from the experimental field to ascertain the nutrient status of each plot of the experiment at 0-15 and 15-30 cm depth at the time of inception of the experiment during kharif season (pooled data of tow years (2023 and 2024). The size of the soil sample was reduced by air-drying and crusting with the wooden hammer and then passed through a 2 mm sieve, canning and quartering to prepare the composite soil sample for physical and chemical analysis. "The soil sample was analyzed for Bulk density, particle density, %pore space, water holding capacity (%), pH, EC, %Organic carbon, Available N,P, K and Zinc. The data recorded for different characteristics were subjected to statistical analysis by adopting the method of analysis of variance (ANOVA) as described by Gomez and Gomez (1984)".

3. RESULTS AND DISCUSSION

Data in respect of soil health studies in terms of physical and chemical properties of soil as influenced by different INM treatments after harvest of rice at 0-15 and 15-30 cm depth in pooled data of two year 2023 and 2024 are presented in Tables 1 and 2. The results regarding bulk density Mg m^{-3} of soil after harvest of rice crop was non-significant due to different treatment. The minimum bulk density (1.078 and 1.097 Mg m^{-3}) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the maximum bulk density (1.3368 and 1.442 Mg m^{-3}) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. "It might due to use of INM that increased biomass of plant that biomass increase the organic carbon resulted in more pore space and good soil aggregation." Similar results were also reported by (Paliwal & Golani, 2021; Kumar *et al.,* 2022; Pallavi and Govindrao 2020; Prakash *et al.,* 2024; Mishra *et al.,* 2017). Surya et al. (2022) and Kumar et al. (2020) also observed a similar trend. The results regarding particle density Mg m^{-3} of soil after harvest of rice crop was non- significant due to different treatment. The maximum particle density (2.64 and 2.66 Mg m^{-3}) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the minimum particle density (2.36 and 2.39 Mg m^{-3}) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. INM fertilizer impact on particle density at 0-15 cm soil depth. Due to FYM and Sheep manure pore space will be increased and impact on particle density at 0-15 cm depth positively means lowest particle density observed in T1. This may be due to higher organic carbon concentration in soil which is an important component of soil solids. Similar results were also reported by (Paliwal & Golani 2021; Kumar *et al.,* 2022; Pallavi & Govindrao 2020; Prakash *et al.,* 2024; Mishra *et al.,* 2017). A similar findings were also discussed by Surya et al. (2022) and Kumar et al. (2020). The results regarding pore space (%) of soil after harvest of rice crop was significant due to different treatment. The maximum pore space (%) (49.51 and 49.50) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the minimum pore space (%) (47.30 and 47.26) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. "It's indicated that when dose of INM fertilizer increases pore space also increased in 0-15 cm soil depth but when depth increases pore space decreased means at 15-30 cm, and leguminous crop is also nitrogen fixation crop, its clearly show that INM changed non-significant on pore space". Similar results were also reported by (Paliwal & Golani 2021; Kumar *et al.,* 2022; Pallavi & Govindrao 2020; Prakash *et al.,* 2024; Mishra *et al.,* 2017) Surya et al. (2022) and Kumar et al. (2020) also observed a similar finding. The results regarding water holding capacity (%) of soil after harvest of rice crop was significant due to different treatment. The maximum water holding capacity (%) (52.22 and 52.00) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the minimum water holding capacity (%) (48.68 and 48.18) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. Due to use of INM fertilizer influence biomass production and these biomass soil organic carbon into soil that organic carbon increased the water holding capacity positively. Similar results were also reported by Hanoon *et al.,* (2020), (Kumar *et al.,* 2022; Pallavi and Govindrao 2020; Prakash *et al.,* 2024; Mishra *et al.,* 2017). Further evaluations were done by Surya *et al.,* 2022 and Kumar *et al.,* 2020). The results regarding pH of soil after harvest of rice crop was non-significant due to different treatment. The minimum pH (6.82 and 6.81) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the maximum pH (7.40 and 7.37) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. Due to use of INM soil is not able to be attributed to the acid producing nature and release of organic acids during mineralization of FYM and Vermicompost helps to decrease soil pH. Similar results were also reported by Mamatha et al. (2018); Kumar *et al.,* (2022). Further findings were reported by Pallavi & Govindrao 2020; Prakash *et al.,* 2024; Mishra *et al.,* 2017; Surya *et al.,* 2022 and Kumar *et al.,* 2020). The results regarding EC (dS m^{-1}) of soil after harvest of rice crop was non-significant due to different treatment. The minimum EC (dS m^{-1}) (0.214 and 0.216) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the maximum EC (dS m^{-1}) (0.409 and 0.394) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. The decrease EC might be due to the release of different organic acid during the decomposition process which solubilized the salt and that leached down trough irrigation. Similar results were also reported by Meena *et al.,* (2017), (Kumar *et al.,* 2022; Pallavi & Govindrao 2020; Prakash *et al.,* 2024). Similar findings were also discussed by Mishra *et al.,* (2017); Surya *et al.,* (2022) and Kumar *et al.,* (2020). The results regarding Organic carbon (%) of soil after harvest of rice crop was significant due to different treatment. The maximum Organic carbon (%) (0.552 and 0.548) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the minimum Organic carbon (%) (0.432 and 0.425) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. It might due to INM fertilizer effect is further enhanced that improved the root and shoot growth. Higher production of root biomass might have increased the organic carbon

Table 1. Response of Integrated nutrient management on physico-Chemical properties of Soil of rice in inceptisols of Prayagraj (Pooled data of two years 2023 and 2024)

S. No.	Treatments No.	Bulk Density (Mg m-3)		Particle density (Mg m-3)		Pore space (%)		Water holding capacity (%)		pH		EC (dS m^{-1})	
		0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm	0-15 cm	15-30 cm
1	T_1	1.368	1.442	2.36	2.39	47.30	47.26	48.68	48.18	7.40	7.37	0.409	0.394
2	T_2	1.224	1.241	2.50	2.51	49.14	49.12	50.90	50.59	7.10	7.09	0.252	0.252
3	T_3	1.197	1.212	2.36	2.37	49.21	49.20	51.00	50.68	7.08	7.06	0.243	0.245
4	T_4	1.297	1.362	2.36	2.38	48.13	48.10	49.62	49.38	7.33	7.31	0.372	0.342
5	T_5	1.293	1.347	2.38	2.40	48.32	48.28	49.69	49.48	7.28	7.27	0.334	0.326
6	T_6	1.257	1.323	2.39	2.40	48.47	48.45	49.88	49.66	7.25	7.24	0.326	0.322
7	T_7	1.144	1.159	2.55	2.56	49.30	49.29	51.30	51.08	6.95	6.94	0.229	0.230
8	T_8	1.104	1.122	2.61	2.63	49.41	49.40	51.98	51.77	6.87	6.85	0.221	0.221
9	T_9	1.088	1.109	2.63	2.64	49.46	49.44	51.71	51.45	6.85	6.83	0.215	0.218
10	T_{10}	1.240	1.298	2.43	2.44	48.73	48.70	50.28	50.04	7.18	7.17	0.285	0.279
11	T_{11}	1.197	1.262	2.48	2.50	49.09	49.07	50.68	50.44	7.14	7.13	0.258	0.261
12	T_{12}	1.177	1.193	2.53	2.55	49.26	49.26	51.07	50.83	7.05	7.04	0.237	0.233
13	T_{13}	1.123	1.141	2.58	2.59	49.34	49.34	51.59	51.36	6.91	6.90	0.225	0.224
14	T_{14}	1.078	1.097	2.64	2.66	49.51	49.50	52.22	52.00	6.82	6.81	0.214	0.216
15	T_{15}	1.243	1.307	2.41	2.43	48.61	48.59	50.16	49.94	7.21	7.20	0.318	0.364
16	T_{16}	1.212	1.272	2.45	2.47	48.85	48.76	50.64	50.41	7.16	7.15	0.281	0.277
	F-Test	NS	NS	NS	NS	S	S	S	S	NS	NS	NS	NS
	S.Ed.	0.109	0.115	0.147	0.134	0.048	0.031	0.100	0.039	0.178	0.188	0.065	0.059
	C.D. at 5%	-	-	-	-	0.098	0.062	0.205	0.080	-	-	-	-

NS = Non Significant; S = Significant

Table 2. Response of Integrated nutrient management on physico-Chemical properties of Soil of rice in inceptisols of Prayagraj (Pooled data of two years 2023 and 2024)

S. No.	Treatments No.	Organic carbon (%)		Available Nitrogen (kg ha^{-1})		Available Phosphorus (kg ha^{-1})		Available Potassium (kg ha^{-1})		Zinc (mg kg^{-1})	
		0-15 cm	**15-30 cm**	0-15 cm	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**	**0-15 cm**	**15-30 cm**
1	T_1	0.432	0.425	213.020	198.113	11.880	9.943	182.157	172.338	0.215	0.206
2	T_2	0.509	0.500	222.393	207.879	15.078	12.908	192.215	183.065	0.233	0.227
3	T_3	0.520	0.509	222.945	207.062	16.062	12.667	189.008	182.770	0.539	0.527
4	T_4	0.447	0.445	219.182	203.835	14.650	11.498	191.883	180.335	0.563	0.551
5	T_5	0.454	0.450	221.188	204.472	13.878	11.812	189.902	176.222	0.365	0.354
6	T_6	0.460	0.452	222.118	204.732	14.315	12.405	185.255	181.252	0.396	0.383
7	T_7	0.539	0.533	224.092	208.403	16.908	13.622	197.392	192.882	0.247	0.242
8	T_8	0.544	0.541	228.542	212.612	18.388	15.695	202.915	198.902	0.553	0.542
9	T_9	0.549	0.546	238.995	214.658	21.902	19.698	205.742	200.822	0.575	0.565
10	T_{10}	0.482	0.476	225.141	209.123	17.942	14.497	200.078	196.760	0.466	0.428
11	T_{11}	0.491	0.489	226.561	210.510	21.072	18.543	204.702	199.973	0.486	0.454
12	T_{12}	0.530	0.519	241.007	216.141	26.045	21.347	210.982	204.373	0.244	0.236
13	T_{13}	0.541	0.530	245.387	223.807	30.418	25.623	214.388	211.120	0.561	0.547
14	T_{14}	0.552	0.548	250.173	232.852	35.397	30.114	220.790	215.877	0.582	0.572
15	T_{15}	0.474	0.470	243.505	221.325	28.527	24.063	212.018	208.323	0.471	0.436
16	T_{16}	0.485	0.480	247.692	227.765	34.253	29.613	219.399	215.343	0.492	0.463
	F-Test	S	S	S	S	S	S	S	S	S	S
	S.Ed. (±)	0.008	0.003	0.977	1.569	0.496	0.225	0.663	0.719	0.0117	0.0036
	CD at 5%	0.016	0.007	1.996	3.205	1.012	0.459	1.353	1.468	0.0239	0.0074

NS = Non Significant; S = Significant

content. Similar findings were recorded by Wang *et al.,* (2020) and Kumar *et al.,* (2022). Comparable results were also reported by Pallavi & Govindrao 2020; Prakash *et al.,* 2024; Mishra *et al.,* 2017; Surya *et al.,* 2022 and Kumar *et al.,* 2020). The results regarding Available Nitrogen (kg ha^{-1}) of soil after harvest of rice crop was significant due to different treatment. The maximum Available Nitrogen (kg ha^{-1}) (250.173 and 232.852) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the minimum Available Nitrogen (kg ha^{-1}) (213.020 and 1998.113) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. The lower content in untreated plots is a result of mining of available nitrogen with INM fertilizer over a period of time might have helped in the mineralization of soil nitrogen leading to build up of higher available nitrogen leguminous family crop are also nitrogen fixation crop. Similar findings were also recorded by Biswash *et al.,* (2014) and Kumar *et al.,* (2022). Comparable trends were observed in the studies of Pallavi & Govindrao (2020); Prakash *et al.,* 2024; Mishra *et al.,* (2017); Surya *et al.,* (2022) and Kumar *et al.,* (2020). The results regarding Available phosphorus (kg ha^{-1}) of soil after harvest of rice crop was significant due to different treatment. The maximum Available phosphorus (kg ha^{-1}) (35.397 and 30.114) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the minimum Available phosphorus (kg ha^{-1}) (11.880 and 9.943) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. Buildup of Available Phosphorous fertilizer with the application of INM might be due to during decomposition which is turn helped in releasing Phosphorous action of native nitrogen in the Soil, this helps in the release of Phosphorous. Similar findings were also recorded by Upadhyay *et al.,* (2022) and Kumar *et al.,* (2022). Comparable findings were observed in the studies Pallavi & Govindrao 2020; Prakash *et al.,* 2024; Mishra *et al.,* 2017; Surya *et al.,* 2022 and Kumar *et al.,* 2020). The results regarding Available potassium (kg ha^{-1}) of soil after harvest of rice crop was significant due to different treatment. The maximum Available potassium (kg ha^{-1}) (220.790 and 215.877) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the minimum Available potassium (kg ha^{-1}) (182.157 and 172.338) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. Similar trend was recorded in both soil depth. Increase in available potassium due to addition of may be ascribed to the reduction of potassium fixation and release of potassium due to interaction of INM fertilizer with clay, besides the direct potassium addition to the pool of soil such increase in the content of available potassium with the use of INM fertilizer has also been reported by Ali *et al.,* (2021), (Kumar *et al.,* 2022; Pallavi & Govindrao, 2020). Consistent trends have been documented by several researchers Prakash *et al.,* (2024); Mishra *et al.,* (2017); Surya *et al.,* (2022) and Kumar *et al.,* (2020). The results regarding Available Zinc (mg kg^{-1}) of soil after harvest of rice crop was significant due to different treatment. The maximum Available Zinc (mg kg^{-1}) (0.582 and 0.572) at 0-15cm and 15-30 cm depth was found in treatment T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA. Whereas the minimum Available Zinc (mg kg^{-1}) (0.215 and 0.206) at 0-15 and 15-30 cm depth was found in T1 Control after harvest of rice crop in pooled data. Similar findings were also recorded by (Kumar *et al.,* 2022; Pallavi and Govindrao 2020; Prakash *et al.,* 2024). Mishra *et al.,* 2017; Surya *et al.,* 2022; Kumar *et al.,* 2020 and Jajra *et al.,* 2022 also reported the similar findings. In contrast, the foliar application of zinc significantly enhances the levels of nitrogen, phosphorus, potassium, and zinc following the harvest of rice. The rise in available zinc in the soil may be attributed to the synergistic interaction between nitrogen and zinc. The treatments enriched with zinc demonstrated an increase in the Zn content of the soil, which can be ascribed to the varying amounts of fertilizer zinc that likely contributed additional Zn to the soil reservoir. A comparable outcome was noted in the studies conducted by Fulpagare *et al.* (2018), Jain *et al.* (2018), Karrimi *et al.* (2018), and Daphade *et al.* (2019).

4. CONCLUSION

it is concluded that the treatment combination T_{14}: RDF @100% + @100% Vermicompost + @ 100% Zn SA shows best result on physico-chemical properties of soil after harvest rice crop in comparison to other treatment combination.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author(s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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