Response of zinc application under integrated plant nutrient supply in aerobic rice of Inceptisol

SP SINGH and SHILPA KAUSHIK

ICAR – Krishi Vigyan Kendra, Indira Gandhi Krishi Vishwavidyalaya
Bilaspur 495001 Chhattisgarh, India
Email for correspondence: spsinghsahab@gmail.com

Received: 04.01.2023/Accepted: 03.02.2023

ABSTRACT

Field experiment was conducted at instructional farm of Krishi Vigyan Kendra, Raigarh, Chhattisgarh during kharif 2019 to investigate the response of zinc application under integrated plant nutrient supply in aerobic rice of Inceptisol. The experiment was laid out in randomized block design comprising thirteen treatments consisting of different combinations with three replications. The results revealed that the rice responded significantly to graded doses of zinc application. All the treatments containing Zn enhanced grain yield from 15.96 to 61.14 per cent over control. However, there was no effect observed in case of straw yield, where the increase was observed from 10.59 to 40.33 per cent. The treatment containing $ZnSO_4$ 25 kg/ha, was superior over control, though at par with some other treatments for N, P K and Zn content in rice grain and straw. The N, K and Zn uptake in grain and straw was recorded maximum in treatments RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter* and RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*. The P uptake in straw was the maximum in the former treatment. The N, P, K and Zn uptake increased with the increase in Zn content up to 25 tonnes/ha but decreased when the Zn dose was increased. The net return increased from Rs 25,383.00 to 50,863.00 in various Zn containing treatments as compared to Rs 20,352.00 in control. Maximum B-C ratio of 2.10 was recorded in treatment containing Zn 25 kg/ha as compared to 1.51 recorded in control.

Keywords: Zinc: response: yield: economics; rice

INTRODUCTION

Zinc is one of the most important yield-limiting essential micronutrient necessary for normal growth and development of plants. It is among eight micronutrients essential for plants. Zn is ranked as the fourth most deficient element in Indian soils after N, P and K . Shukla and Behera (2011) reported that 49 per cent of the Indian soils are deficient in Zn. However, zinc deficiency in plants retards photosynthesis and nitrogen metabolism, reduces flowering and fruit development, prolongs growth periods (resulting in delayed maturity), decreases yield and quality and results in sub-optimal nutrient-use efficiency. Zinc is important in plants as a structural component and a regulatory co-factor for a variety of enzymes and proteins involved in various biochemical pathways. These pathways include photosynthesis, sugar to starch conversion, carbohydrate, protein and auxin metabolism, pollen formation, maintenance of the integrity of biological membranes and resistance to infection by certain pathogens. Rice is the stable food for more than half of the world population and it provides 21 and 15 per cent per capita of dietary energy and protein currency, respectively (Maclean et al 2002). Being the single major source of agricultural GDP, rice plays a significant role in the economy. Considering the intensive cultivation of high yielding rice varieties and Inceptisol in the rice growing areas of Chhattisgarh, the response of rice to applied Zn is the subject deserving investigation. In Chhattisgarh, most of the cultivable land especially rice growing soils are showing Zn deficiency and information in relation to Zn fertilizer management is inadequate. As a result, a viable alternative would be to take advantage of certain soil microorganisms to solubilize these fixed forms of Zn into labile Zn forms for increased availability and subsequent uptake by plants (Prajapati et al 2021). Some microorganisms such as *Pseudomonas* sp, *Gluconacetobacter* sp, *Thiobacillus* sp, *Bacillus* sp, *Acinetobacter* sp etc are reported as potential Zn solubilizers. The beneficial effect of FYM might be due to its favorable effect on the availability of macro and micronutrients and better uptake of nutrients by rice grain and straw as compared to RDF (100% NPK) alone (Agarwal 2008). However, response to zinc application was observed in zinc deficient areas, but an optimum level of zinc has not been determined in relation to agro-climatic conditions of state. Hence, the present study was designed with an objective to find out a suitable level of zinc fertilizer with zinc solubilizing bacteria (ZSB) to supply the zinc requirement to increase the yield, productivity, nutrient uptake and economics of rice in Inceptisol.

MATERIAL and METHODS

Field experiment was conducted at the instructional farm of Krishi Vigyan Kendra, Raigarh, Chhattisgarh during kharif 2019 to investigate the response of zinc application under integrated plant nutrient supply in aerobic rice of Inceptisol. The experimental site was located on the northern part of Chhattisgarh state and lied at 21°54' N latitude and 83°24' E longitude with an altitude of 215 m amsl. The soil of the experimental field was an Inceptisol of silty clay loam texture with pH 6.50, EC 0.13 dS/m, organic carbon (OC) 5.0 g/kg, available nitrogen 210 kg/ha, available phosphorus 20.83 kg/ha, available potash 295 kg/ha and available zinc 2.17 mg/kg. The experiment was laid out in randomized block design (RBD) comprising thirteen treatments consisting of different combinations viz T_1 [Control (RDF: NPKZn 100:60:40:0 kg/ha)], T_2 [RDF: NPKZn 100:60:40:5 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + microbial consortia (ZSB) (*Acinetobacter calcoaceticus* × *Pantoea agglomerans*) + phosphorus solublizing bacteria (PSB) + *Azotobactor*], T_3 (RDF: NPKZn 100:60:40:10 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_4 (RDF: NPKZn 100:60:40:15 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_5 (RDF: NPKZn 100:60:40:20 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_6 (RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_7 (RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_8 [75% (RDF: NPKZn 100:60:40:5 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_9 [75% (RDF: NPKZn 100:60:40:10 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{10} [75% (RDF: NPKZn 100:60:40:15 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{11} [75% (RDF: NPKZn 100:60:40:20 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{12} [75% (RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)] and T_{13} [75% (RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], replicated thrice. Recommended dose of N, P, K and Zn through urea, SSP, MoP and $ZnSO_4$ were applied @ 100 kg N + 60 kg P_2O_5 + 40 kg K_2O/ha along with 3 tonnes/ha vermicompost and 5 tonnes/ha farmyard manure (FYM) as broadcast and incorporated into the soil by puddling just before transplanting.

Application of nitrogen was done in three splits viz basal (50%), maximum tillering (25%) and panicle initiation stage (25%). Cultural practices such as weeding and plant protection measures etc were done. The crop variety IGKV R-1 (Rajeshwary) was used as a test crop. Twenty two days old seedlings were transplanted with three seedlings with three plants per hill at a spacing of 20 cm x 20 cm surrounded by 30 cm wide bunds. Grain and straw yields were recorded of harvested rice at maturity. For analysis of zinc content in dried grain and straw, samples were digested in diacid mixture and determined in atomic absorption spectrophotometer. Zinc uptake was calculated by multiplying factor in grain and straw yield with respective zinc content. Five plants were selected randomly from each plot for sampling purpose and observations were recorded. The data regarding yield attributes, nutrient composition and nutrient uptake were analysed with statistical tools.

RESULTS and DISCUSSION

Yield attributes: The grain yield ranged from 3.55 to 5.35 tonnes/ha in various Zn applications which were at par. Significantly higher grain yield (5.35 tonnes/ha) was recorded in T_6 (RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*) than control (3.32 tonnes/ha). The straw yield ranged from 5.38 to 7.55 tonnes/

Table 1. Effect of zinc on grain and straw yield and economics of rice

Treatment	Grain yield (tonnes/ha)	Increase in grain yield over control (%)	Straw yield (tonnes/ha)	Increase in straw yield over control (%)	Gross return (Rs/ha)	Net return (Rs/ha)	B-C ratio
T_1	3.32	-	5.38	-	60,258.00	20,352.00	1.51
T_2	3.85	15.96	5.95	10.59	69,878.00	26,743.00	1.62
T_3	4.28	28.91	6.43	19.51	77,682.00	33,292.00	1.75
T_4	4.45	34.03	6.65	23.60	80,768.00	37,806.00	1.88
T_5	4.68	40.96	6.88	27.28	84,942.00	41,157.00	1.94
T_6	5.35	61.14	7.55	40.33	97,103.00	50,863.00	2.10
T_7	5.12	54.21	7.32	36.05	92,928.00	46,695.00	2.01
T_8	3.55	6.92	5.67	05.39	64,433.00	25,383.00	1.65
T_9	3.78	13.85	5.78	07.43	68,607.00	28,719.00	1.72
T_{10}	4.25	28.01	6.25	16.17	77,138.00	34,283.00	1.80
T_{11}	4.52	36.14	6.43	19.51	82,038.00	38,168.00	1.87
T_{12}	4.85	46.08	6.58	22.30	88,027.00	42,180.00	1.92
T_{13}	4.67	40.66	6.35	18.02	84,761.00	41,294.00	1.95
SEm±	0.68	-	1.23	-	-	-	0.02
$CD_{0.05}$	1.87	-	NS	-	-	-	0.06

T_1 [Control (RDF: NPKZn 100:60:40:0 kg/ha)], T_2 [RDF: NPKZn 100:60:40:5 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + microbial consortia (ZSB) (*Acinetobacter calcoaceticus* × *Pantoea agglomerans*) + phosphorus solublizing bacteria (PSB) + *Azotobactor*], T_3 (RDF: NPKZn 100:60:40:10 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_4 (RDF: NPKZn 100:60:40:15 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_5 (RDF: NPKZn 100:60:40:20 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_6 (RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_7 (RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_8 [75% (RDF: NPKZn 100:60:40:5 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_9 [75% (RDF: NPKZn 100:60:40:10 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{10} [75% (RDF: NPKZn 100:60:40:15 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{11} [75% (RDF: NPKZn 100:60:40:20 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{12} [75% (RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{13} [75% (RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)]

ha, however, there were no significant differences in straw yield among various treatments containing Zn and all were at par with control.

Das et al (2019) reported that increase in yield with basal application of $ZnSO_4$ 25 kg/ha might be due to the greater amount of Zn uptake. Ghoneim (2016) reported that Zn application by different methods, significantly increased number of tillers, panicles, plant height, 1000-grain weight, filled grains percentage and grain yield of Sakha 104 rice. They opined that the increase in grain yield with the application of zinc might be attributed to adequate supply of zinc that might have increased the availability and uptake of other essential nutrients resulting in improvement in metabolic activities and also due to the effect of zinc on the proliferation of roots. Similar findings were also reported by Muthukumaraja and Sriramachandrasekharan (2013) who were of the opinion that the increment in seed yield might be due to improvement in soil quality with the application of vermicompost, farmyard manure, biofertilizers and instant availability of nutrients from inorganic fertilizers.

Nutrient content and uptake: The data pertaining to nutrient content in grain and straw are summarized in Table 2. The application of organic manures and microbial inoculants along with recommended dose of fertilizers led to significant increase in nutrient content. The highest N content in grain (1.80%) was recorded due to T_6. The highest N content in straw 0.46, 0.50, 0.48, 0.47 and 0.49 per cent was recorded in T_5 (RDF: NPKZn 100:60:40:20 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_6, T_7 (RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_{12} [75% (RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)] and T_{13} respectively, which were at par. P content in grain was highest in T_6 (0.38%), T_7 (0.36%) and T_{13} [75% (RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/

Table 2. Effect of zinc on nitrogen, phosphorus, potassium and zinc content in rice grain and straw

Treatment	Nitrogen (%)		Phosphorus (%)		Potassium (%)		Zinc (mg/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	1.42	0.40	0.23	0.10	0.40	1.30	14.50	30.15
T_2	1.47	0.42	0.26	0.11	0.42	1.32	18.20	32.40
T_3	1.52	0.43	0.28	0.12	0.44	1.35	22.50	35.72
T_4	1.62	0.45	0.31	0.13	0.45	1.37	25.75	38.50
T_5	1.68	0.46	0.34	0.15	0.46	1.42	27.56	41.25
T_6	1.80	0.50	0.38	0.18	0.50	1.50	35.30	46.30
T_7	1.75	0.48	0.36	0.16	0.47	1.47	32.60	44.65
T_8	1.46	0.41	0.22	0.11	0.41	1.31	16.40	35.60
T_9	1.52	0.43	0.26	0.13	0.43	1.34	19.65	38.25
T_{10}	1.65	0.45	0.29	0.14	0.45	1.38	23.50	40.65
T_{11}	1.67	0.45	0.31	0.15	0.46	1.42	27.35	41.85
T_{12}	1.72	0.47	0.33	0.16	0.48	1.46	31.45	44.50
T_{13}	1.75	0.49	0.36	0.18	0.49	1.48	33.62	45.30
SEm±	0.012	0.011	0.006	0.002	0.006	0.022	048	1.46
$CD_{0.05}$	0.040	0.040	0.020	0.006	0.017	0.068	1.06	4.07

T_1 [Control (RDF: NPKZn 100:60:40:0 kg/ha)], T_2 [RDF: NPKZn 100:60:40:5 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + microbial consortia (ZSB) (*Acinetobacter calcoaceticus* × *Pantoea agglomerans*) + phosphorus solublizing bacteria (PSB) + *Azotobactor*], T_3 (RDF: NPKZn 100:60:40:10 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_4 (RDF: NPKZn 100:60:40:15 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_5 (RDF: NPKZn 100:60:40:20 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_6 (RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_7 (RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*), T_8 [75% (RDF: NPKZn 100:60:40:5 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_9 [75% (RDF: NPKZn 100:60:40:10 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{10} [75% (RDF: NPKZn 100:60:40:15 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{11} [75% (RDF: NPKZn 100:60:40:20 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{12} [75% (RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)], T_{13} [75% (RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)]

ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobactor*)] (0.36%), which were at par. In straw, highest P content of 0.18 per cent was recorded in T_6 and T_{13} each. K content in grain was recorded maximum in T_6 (0.50%) and T_{13} (0.49%), the two being at par. On the other hand, highest K in straw was observed in T_6 (1.50%), T_7 (1.47%), T_{12} (1.46%) and T_{13} (1.48%), all being at par. In case of Zn, highest content in grain was recorded in T_6 (35.30 mg/ha). In case of straw, maximum Zn content was observed in T_6 (46.30 mg/ha), T_7 (44.65 mg/ha), T_{12} (44.50 mg/ha) and T_{13} (45.30 mg/ha), all being at par.

The data on nutrients uptake in rice grain and straw are given in Table 3. The N uptake in grain (93.62 and 92.16 kg/ha) and straw (36.60 and 36.24 kg/ha); P uptake in grain (19.45 and 19.26 kg/ha); K uptake in grain (25.60 and 25.14 kg/ha) and straw (109.80 and 110.98 kg/ha) and Zn uptake in straw (340.38 and 337.63 g/ha) was recorded maximum in T_6 and T_7 respectively, as compared to T_1 and T_8, the latter two being at par. The P uptake in straw was maximum (13.17 kg/ha) in T_6 and lowest in control (5.38 kg/ha). Zn uptake in grain was maximum in T_6 (180.73 g/ha) and T_7 (174.41 g/ha), the two being at par, as compared to 48.14 g/ha in control. It can be seen that N, P, K and Zn uptake increased with the increase in Zn content up to 25 tonnes/ha but decreased when the Zn dose was increased.

During decomposition of FYM and vermicompost the beneficial effect on nitrogen content is observed as decomposition greatly alters soil pH as a result of the release of basic cations, NH_3 and NH_4^+ production and increased microbial activity. Similar positive effect of zinc fertilizers and microbial inoculation on nitrogen concentration and uptake was reported by Shahane et al (2019). The recommended doses of fertilizer treatments along with organic and microbial inoculation significantly increased phosphorus concentration in grain and straw over control. It could be due to the reason that zinc has a strong antagonistic interaction with phosphorus and prevents P mobilization from the root to the top of the plant (Yadav and Singh

Table 3. Effect of zinc on nitrogen, phosphorus, potassium and zinc uptake by rice grain and straw

Treatment	Nitrogen (kg/ha)		Phosphorus (kg/ha)		Potassium (kg/ha)		Zinc (g/ha)	
	Grain	Straw	Grain	Straw	Grain	Straw	Grain	Straw
T_1	47.14	21.52	7.63	5.38	13.28	69.94	48.14	162.74
T_2	56.59	24.99	10.01	6.54	16.17	78.54	70.07	193.37
T_3	65.05	27.64	11.98	7.71	18.83	86.80	96.30	229.22
T_4	72.09	29.92	13.79	8.64	20.02	91.10	114.58	254.36
T_5	78.62	31.64	15.91	10.32	21.52	97.69	128.98	284.48
T_6	93.62	36.60	19.45	13.17	25.60	109.80	180.73	340.38
T_7	92.16	36.24	19.26	12.08	25.14	110.98	174.41	337.63
T_8	51.83	23.24	7.81	6.23	14.55	74.27	58.22	176.90
T_9	57.45	24.85	9.82	7.51	16.25	77.45	74.27	192.18
T_{10}	70.12	28.12	12.32	8.75	19.12	86.25	99.87	221.43
T_{11}	75.48	28.93	14.01	9.64	20.79	91.30	123.62	254.94
T_{12}	83.42	30.92	16.00	10.52	23.28	96.06	152.53	278.33
T_{13}	81.72	31.11	16.81	11.43	22.88	93.98	157.00	287.02
SEm±	2.23	0.74	0.65	0.23	0.82	2.56	3.52	7.56
$CD_{0.05}$	6.13	2.03	1.78	0.63	2.25	7.04	9.01	19.35

T_1 [Control (RDF: NPKZn 100:60:40:0 kg/ha)], T_2 [RDF: NPKZn 100:60:40:5 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + microbial consortia (ZSB) (*Acinetobacter calcoaceticus* × *Pantoea agglomerans*) + phosphorus solublizing bacteria (PSB) + *Azotobacter*], T_3 (RDF: NPKZn 100:60:40:10 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*), T_4 (RDF: NPKZn 100:60:40:15 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*), T_5 (RDF: NPKZn 100:60:40:20 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*), T_6 (RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*), T_7 (RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*), T_8 [75% (RDF: NPKZn 100:60:40:5 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*)], T_9 [75% (RDF: NPKZn 100:60:40:10 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*)], T_{10} [75% (RDF: NPKZn 100:60:40:15 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*)], T_{11} [75% (RDF: NPKZn 100:60:40:20 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*)], T_{12} [75% (RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*)], T_{13} [75% (RDF: NPKZn 100:60:40:30 kg/ha + vermicompost 3 tonnes/ha + FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter*)]

2021). The combination of fertilizers along with microbial inoculation (ZSB) and Zn fertilizer application significantly improved potassium content and uptake over non-inoculated (Suganya et al 2020). The Zn application gradually increased the Zn content and Zn in grain and straw with increase in zinc level up to $ZnSO_4$ 25 kg/ha and decreased at 30 kg/ha. Singh et al (2018) also reported that zinc application increases Zn content and uptake in grain and straw in Inceptisol. Ghoneim (2016) reported that among the different Zn applications, soil application of 15 kg/ha as $ZnSO_4.H_2O$ caused highest increase in total N percentage, total K percentage and available Zn content in both rice grain and straw, however, the percentage of total P decreased significantly. Zinc content in soil after harvesting was significantly affected by Zn application.

Economic analysis: The results given in Table 1 indicate the response of zinc application under integrated plant nutrient supply on economics of aerobic rice. The net return increased from Rs 25,383.00 to 50,863.00 in various Zn containing treatments as compared to Rs 20,352.00 in control. Maximum B-C ratio of 2.10 was recorded in treatment containing Zn 25 kg/ha followed by 2.01 and 1.95 in treatments containing Zn 30 kg/ha and with 100 and 75 per cent doses of the treatments respectively, the latter two being at par, as compared to 1.51 recorded in control. This shows that the treatments were highly remunerative and treatments had economic viability in absolute terms. In overall, the application of $ZnSO_4$ 25 kg/ha proved significantly beneficial in respect of yield and economics of rice grown in Inceptisol. The findings are in close conformity with the work of Singh et al (2018) and Prajapati et al (2022).

CONCLUSION

The present study revealed that rice responded significantly to graded doses of zinc application. Overall best results were recorded at $ZnSO_4$ 25 kg/ha. Economic analysis of different treatments revealed that gross return, net return and B-C ratio were recorded highest with the treatment containing $ZnSO_4$ 25 kg/ha.

Therefore, treatment consisting of RDF: NPKZn 100:60:40:25 kg/ha + vermicompost 3 tonnes/ha+ FYM 5 tonnes/ha + ZSB + PSB + *Azotobacter* is recommended for higher net return in rice cultivation. The application of reduced quantity of chemical fertilizers along with organics and microbial inoculants gave better results in terms of yield and yield attributing traits and proved better sustainable integrated plant nutrients supply option for farmers.

REFERENCES

Agarwal M 2008. Monitoring soil physical, chemical and microbiological properties and nutrients uptake after 35 years of continuous fertilizer use in rice-wheat system. PhD Thesis, Govind Ballabh Pant University of Technology and Agriculture, Pantnagar, Uttarakhand, India, 153p.

Das S, Green A and Fan MX 2019. Zinc deficiency in Indian soils is associated with low crop productivity and crop quality. Better Crops – South Asia, pp 11-14.

Ghoneim AM 2016. Effect of different methods of Zn application on rice growth, yield and nutrients dynamics in plant and soil. Journal of Agriculture and Ecology Research International **6(2):** 1-9.

Maclean JL, Dawe DC, Hardy B and Hettel GP 2002. Rice almanac. 3rd Edn, CABI Publishing, Wallingford, Oxon, 253p.

Muthukumararaja T and Sriramachandrasekharan MV 2013. Response of rice genotypes to zinc fertilization in Typic Haplustert soil. Indian Journal of Applied Research **3(5):** 27-29.

Prajapati J, Yadav J and Prajapati BK 2021. Effect of zinc solubilising bacteria on root colonization and zinc uptake in rice (*Oryza sativa*). Annals of Plant and Soil Research **23(2):** 232-234.

Prajapati J, Yadav J and Prajapati BK 2022. Effect of zinc fertilizers and Zn solubilizing bacteria on yield, nutrient uptake and economics of rice (*Oryza sativa* L). Annals of Plant and Soil Research **24(2):** 226-230.

Shahane AA, Shivay YS, Prasanna R and Kumar D 2019. Improving water and nutrient use efficiency in rice by changing crop establishment methods, application of microbial inoculations and Zn fertilization. Global Challenges **3(10):** 1-14.

Shukla AK and Behera SK 2011. Zinc management in Indian agriculture: past present and future. Indian Journal of Fertilizers **7(10):** 14-33.

Singh SP, Paikra KK and Patel CR 2018. Response of zinc application on aerobic rice in Inceptisols of Raigarh district in Chhattisgarh plains. International Journal of Science and Research **7(1):** 1001-1003.

Suganya A, Saravanan A and Manivannan N 2020. Role of zinc nutrition for increasing zinc availability, uptake, yield and quality of maize (*Zea Mays* L) grains: an overview. Communications in Soil Science and Plant Analysis **51:** 2001-2021.

Yadav K and Singh V 2021. Effect of sulphur and zinc management on yield, quality and nutrient uptake in pearl millet (*Pennisetum glaucum*)-lentil (*Lens culinaris*) crop sequence. Annals of Plant and Soil Research **23(2):** 135-139.