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Research Article

Zn Biofortification through Mineral Fertilization and its Impact on Yield of Various Rice Genotypes

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Abstract

Rice needs micronutrients to grow to its full capacity, and zinc is one of the micronutrients that is most frequently lacking in both rice grains and soil. Two field experiments were conducted at Tamil Nadu Rice Research Institute, Aduthurai (110 N attitude, 790 31’ E longitude, 19.4 MSL) during Kharif and Rabi season respectively to evaluate and compare the application of different sources of Zinc with four Zinc efficient genotypes (CO 47, CO 51, ADT 37, ADT 47). The results showed that, among the genotypes, CO 51 performed well with respect to grain yield, straw yield, grain Zn content and straw Zn content followed by Co 47 followed by ADT 47 and ADT 37 in both the seasons. Among the soil application, Zn chelate recorded higher yield in all the genotypes, whereas among the combination, soil application of zinc sulphate as enriched Farmyard Manure along with foliar application of 0.5% $ZnSO_4$ thrice recorded higher yield when compared to all other treatments.

Keywords: Zinc; Biofortification; Efficient Genotypes; Chelation; Farmyard Manure

Introduction

More over half of the world’s population depends on rice, which is the most significant food crop in the world. Asia is where more than 90% of the world’s rice is grown and consumed. India produced 112.76 million metric tonnes of rice during 2017 and 2018, making it the second-largest producer behind China. The human metabolism is impacted by the shortage or buildup of critical amino acids, minerals, and vitamins due to an unbalanced supply of these nutrients. The World Health Organisation cites zinc deficiency as the fifth most significant cause of illness and disease in underdeveloped nations and the eleventh worldwide. The prevalence of zinc deficiency in soils has been calculated to be around 20% globally. Diarrhoea and respiratory illnesses brought on by zinc deficiency result in 400,000 fatalities worldwide each year. Poor growth, loss of appetite, skin lesions, reduced taste acuity, delayed wound healing, hypogonadism, delayed sexual maturation, and impaired immune response are also symptoms of zinc deficiency. In India, zinc malnutrition costs the nation 1.31 million disability-adjusted life years (DALYs) each year.

The term “biofortification” refers to increasing the amount of bioavailable micronutrients in food crops through plant breeding and genetic selection. Low bioavailability of Zn in soil generally results in Zn deficiency in rice plants, and thus becomes one of the common constraints for Zn biofortification in rice grains [23]. Zn deficiency in rice can be alleviated through Zn fertilization, which is considered to be a cost-effective method to alleviate Zn malnutrition. Zn fertilization to cereal crops improves productivity and grain Zn concentration and thus contributes to grain nutritional value for human beings. However, the vast majority of Zn fertilizer trials and resulting fertilizer recommendations in rice have been in the context of managing the Zn deficiency, with very few studies related to Zn biofortification [4]. Selection of appropriate Zn sources for soil application is considered to be an alternative strategy to improve plant availability of Zn under lowland conditions [16]. Generally, $ZnSO_4$ is the most widely applied Zn source for its high solubility and low cost. In addition, Zn-EDTA (ethylene diamine tetra acetic acid) is also being recommended due to its efficiency of Zn availability for the plant. However, varied responses of crops to the Zn fertilizers have been reported, depending on the source, application time, methods as well as soil chemical properties, which are also influenced by water management (16). The purposes of the present study are: [1] to compare the effectiveness of a Zn fertilizer source ($ZnSO_4$ and Zn-EDTA) and efficient rice genotypes to investigate the ability of different sources could increase grain yield, Zn accumulation in rice grain and Zn bioavailability.

Materials and Methods

Two field experiments were conducted at TRRI, Aduthurai (11^0 N latitude, 79^0 31' E longitude, 19.4 MSL) during Kharif and Rabi season respectively. During normal years, the annual rainfall is 1200 mm of which around 70% is received during September to October (Northeast monsoon). The climate of the experimental site (Cauvery Delta) is sub tropical monsoon type. Two rice crops, one during kharif (kuruvai) transplanting in May- June and harvest in August-September and the second during rabi (thaladi) transplanting in October-November and harvest in January were grown under irrigated conditions every year. The soil of the experimental site is fine montmorillonitic, isohyperthermic, Udorthentic Chromusterts with heavy clay texture belonging to Kalathur soil series. The experiments were conducted in split plot design with three replications and the treatments structure is as follows

Main plots	**Zn efficient genotypes- Four (CO 47, CO 51, ADT 37, ADT 47)**
Sub plots	Zinc treatments -10 T1: RDF (150: 50: 50 kg NPK/ha) T2: RDF + 25 kg $ZnSO_4$ ha^{-1} as soil application T3: RDF + 50 kg $ZnSO_4$ ha^{-1} as soil application T4: RDF + 100 kg $ZnSO_4$ ha^{-1} as soil application T5: T2 + Foliar application of 0.5 % $ZnSO_4$ thrice T6: T3+ Foliar application of 0.5 % $ZnSO_4$ thrice T7: T4+ Foliar application of 0.5 % ZnSO4 thrice T8: RDF + Zn chelate @ 5 kg ha^{-1} as soil application T9: RDF + Zn chelate @ 5 kg ha^{-1} as soil+ 0.5 % $ZnSO_4$ foliar spray thrice T10: RDF +25 kg $ZnSO_4$ as enriched FYM +0.5 % $ZnSO_4$ foliar spray thrice

Table 1

In this study, various levels of chemical fertilizers and combination of fertilizers with chelates and organics were compared. All the plots were received the uniform recommended dose of 150:50:50 NPK kg/ha in both the experiments. Nitrogen was applied in four equal splits for kharif (basal, 15, 30, 45 days after transplanting), while phosphorus and zinc were applied entirely as basal and potassium in two equal splits (as basal and at panicle initiation stage). Foliar application of 0.5% $ZnSO_4$ was applied thrice at 50% flowering, milky and dough stages. A uniform plot size of 20 m^2 was adopted. Need based plant protection measures were taken up against pest and diseases.

The soil of experimental site was clayey (*Typic Haplustert*), having pH 7.4, organic carbon 0.12%, available N 115 kg ha^{-1}, P 52 kg ha^{-1} and K 333 kg ha^{-1} and Diethylene Triamine Penta Acetic acid-Tri Ethanol Amine (DTPA-TEA) extractable Zn was 0.51 mg kg^{-1} (low).

The crop was harvested at maturity and grain and straw yield were recorded after sun drying. The concentration of Zn in grain and straw was estimated using Atomic Absorption Spectrometer (AAS) (Varian-Agilent) by following standard procedures.

At the end of each experiment, representative post harvest soil samples (0-15 cm) were collected and analysed for pH and EC (1:2.5), organic carbon (22), available N (5), Bray P and 1 N NH_4OAC extractable K. Likewise, the plant samples (grain and straw) were collected and analysed for N (3) P and K (5) and their uptake values were worked out. In order to compare the effect of various treatments on grain and straw yield, soil fertility and nutrient uptake the data were pooled and analysis of variance (ANOVA) was performed using standard statistical procedure for split plot design.

Results and Discussion

Grain yield and straw yield

Regarding grain yield, during Kharif season, application of Zn through soil and foliar spray recorded higher grain yield compared to soil application alone in all the genotypes (Table 1). In that, application of 25 kg $ZnSO_4$ as enriched FYM +0.5% $ZnSO_4$ foliar spray thrice (T10) recorded higher grain yield in all the four genotypes (6260 kg/ha in ADT 37, 6250 in ADT 47, 5895 in CO 51 and 5890 in CO 47). There is no significant difference in yield among the genotypes. Among the soil application, Zn chelate recorded the higher yield (5473 kg/ha). During Rabi season (Table 2), higher grain yield was obtained, when zinc applied through combination of soil and foliar methods compared to soil application alone. Similar to Kharif season, application of 25 kg $ZnSO_4$ as enriched FYM +0.5% $ZnSO_4$ foliar spray thrice (T10) recorded higher grain yield in all the four genotypes (6260 kg/ha in CO 51, 6250 in CO 47, 5995 in ADT 47 and 5865 in ADT 37). There is no significant difference in yield among the genotypes. Among the soil application, Zn chelate recorded the higher yield (5102 kg/ha). The same trend was followed in straw yield also. Regarding straw yield (Table 3,4), among the treatments, application of Zn through soil and foliar application recorded higher straw yield compared to soil application alone in all the genotypes (Table 1,2). Application of 25 kg $ZnSO_4$ as enriched FYM +0.5% $ZnSO_4$ foliar spray thrice (T10) recorded higher straw yield in all the four genotypes (7137 kg/ha in ADT., 7126 in ADT 37., 6900 in CO 51 and 6800 in CO 47) during Kharif season. There is no significant difference in yield among the genotypes. Among the soil application, Zn chelate recorded the higher yield (6816 kg/ha). In Rabi season, (Table 2), application of 25 kg $ZnSO_4$ enriched with FYM + 0.5% $ZnSO_4$ as foliar spray thrice at 50% flowering, milky and dough stages recorded higher grain yield (6092 kg ha^{-1}) compared to soil application alone (Table 2). Among the genotypes, CO 51 recorded higher yield followed by CO 47 followed by ADT 47 and ADT 37. Similar results were observed by Gupta and Kala (1992) they reported that soil application of zinc increased paddy yield. Combination of organic form of fertilizer and inorganic fertilizer resulted in higher yield which was in accordance with (16) reported that organic and chelated sources are superior for increasing the zinc use efficiency in rice, even though the application of inorganic fertilisers to the soil is common. The same trend was followed in straw yield in both the seasons. About 97% increase in rice yield due to zinc fertilization was reported by [1]. It may be due to the fact that zinc fertilization is attributed to its involvement in many metallic enzyme system, regulatory functions and auxin production [18], enhanced synthesis of carbohydrates and their transport to the site of grain production [14]. Higher concentration of zinc concentration in the grain maintained by the application of zinc in the rhizosphere with constant supply coupled with more number of productive tillers per hill and higher zinc uptake might have increased the grain yield [6]. Zinc application in the enriched form with organic manure enhances the fertilizer use efficiency and increases the rice yield. The enrichment of micronutrients with organic manures not only enhances the rate of decomposition but also improves the nutrient status and health of soil. Application of FYM with $ZnSO_4$ increased the DTPA-Zn content in soils [12]. Enhanced grain and straw yield could be due to supply of nutrients especially macro and micronutrients which induced cell division, expansion of cell wall, meristematic activity, photosynthetic efficiency, regulation of water to cells, conducive physical environment, facilitating to better aeration, root activity and nutrient absorption leading to higher rice yield [19].

Zn treatments			**Genotypes**				**Mean**
Mode of application	**Sources**	**Levels(kg ha^{-1})**	**CO 47**	**CO 51**	**ADT 37**	**ADT 47**	
Soil Application	No Zn	0	4530	4532	4890	4880	4700
	$ZnSO_4$	25	5100	5142	5200	5233	5168
		50	5155	5164	5284	5336	5384
		100	5142	5024	5048	5234	5112
		Mean	5132	5110	5177	5267	
	Zn Chelate	5	5242	5324	5542	5786	5473
Soil application + Foliar spraying of 0.5 % $ZnSO_4$ thrice		25	5562	5655	5700	5732	5662
		50	5645	5732	5800	5832	5752
		100	5542	5646	5744	5746	5669
		Mean	5583	5677	5748	5770	
	Zn Chelate	5	5632	5764	5794	5800	5748
	Zn EFYM	25	5890	5895	6260	6250	6073
	SE d	CD					
Zn	36.1	72.2					
V	19.2	16.5					
ZnxV	45	NS					

Table 1: Effect of Zn mineral fertilization on Grain Yield (kg/ha) of Rice genotypes (Kharif).

Zn treatments			Genotypes				Mean
Mode of application	**Sources**	**Levels (kg ha^{-1})**	**CO 47**	**CO 51**	**ADT 37**	**ADT 47**	
Soil Application	No Zn	0	4911	4911	4650	4645	4779
	$ZnSO_4$	25	5323	5356	5203	5165	5261
		50	5307	5459	5278	5287	5332
		100	5169	5357	5265	5147	5234
		Mean	5177	5270	5099	5061	
	Zn Chelate	5	5100	5147	5065	5099	5102
Soil application + Foliar spraying of 0.5 % $ZnSO_4$ thrice		25	5333	5366	5213	5175	5271
		50	5317	5565	5325	5406	5403
		100	5170	5401	5298	5169	5259
		Mean	5315	5407	5240	5226	
	Zn Chelate	5	5145	5247	5078	5099	5142
	Zn EFYM	25	6250	6260	5865	5995	6092
	SE d	CD					
Zn	35.1	73.2					
V	20.2	16.0					
ZnxV	44	88.2					

Table 2: Effect of Zn mineral fertilization on Grain Yield (kg/ha) of Rice genotypes (Rabi).

Grain and straw Zn content

During Kharif season, in grain, Zn content was significantly higher in Zn applied through soil and foliar treatments (Table 5). Among the treatments, application of 25 kg $ZnSO_4$ enriched with FYM + 0.5% $ZnSO_4$ as foliar spray thrice at 50% flowering, milky and dough stages recorded higher grain zinc content in all the four genotypes compared to all other treatments. Among the genotypes, higher Zn content was noticed in CO 51. The grain Zinc content increase was in the order of Co 51> CO 47 > ADT 47 > ADT 37. Regarding straw Zn content, in Kharif crop, the maximum (51.2 ppm) Zn content was recorded in the treatment T10 i.e., application of 25 kg $ZnSO_4$ as enriched FYM +0.5% $ZnSO_4$ foliar spray thrice (Table 9). There is no significant difference between the varieties with repect to straw Zn content. Among the soil application, application of soil chelates @ 5 t/ha recorded the higher Zn uptake compared to other treatments irrespective of rice genotypes. Among the soil application, application of Zn chelates @ 5 kg/ha recorded higher Zn content (25.3 ppm) than other treatments in all the four genotypes. There is no significant difference between varieties in grain Zn content. Regarding the Zn content in grain in rabi season (Table 6), it was significantly higher in soil application with foliar treatments than soil application alone. Application of 25 kg $ZnSO_4$ as enriched FYM +0.5% $ZnSO_4$ foliar spray thrice (T10) recorded higher grain Zn content in all in all the four genotypes. In Rabi crop, as in straw yield, the same trend was followed in straw Zn content also (Table 10). The maximum Zn content was recorded in the treatment i.e., application of 25 kg $ZnSO_4$ as enriched FYM +0.5% $ZnSO_4$ foliar spray thrice. Among the genotypes, Co 51 recorded higher Zn content in straw followed by Co 47 followed by ADT 47 and ADT 37 (42.5 ppm in ADT 47, 41.5 ppm in ADT 37, 40.5 ppm in CO 51 and CO 47). These results are in agreement with the finding of [15] who reported that the soil application of zinc resulted in the increased grain Zn concentration. Foliar Zn application is suitable for producers to improve grain Zn concentration as well as improving Zn bioavailability for human consumption [10].

Grain and straw zinc uptake

In the kharif season, as grain Zn uptake, Zn uptake in straw is also higher in the treatment T10 i.e., application of 25 kg $ZnSO_4$ as enriched FYM +0.5% $ZnSO_4$ foliar spray thrice (365 g/ha) (Table 7). Among the four genotypes, ADT 47 recorded higher Zn uptake (365 g/ha) followed by ADT 37 (360 g/ha) followed by CO 51 and CO47. Among the soil application treatments, application of Zn chelate @ 5 t/ha recorded higher Zn uptake compared to other treatments (265 g/ha). In the Rabi crop, Zn uptake in straw is also higher in the treatment T_{10} i.e., application of 25 kg $ZnSO_4$ as enriched FYM + 0.5% $ZnSO_4$ foliar spray thrice (346 g/ha) (Table 8). Among

Zn treatments			Genotypes				Mean
Mode of application	Sources	Levels (kg ha^{-1})	CO 47	CO 51	ADT 37	ADT 47	
Soil Application	No Zn	0	5520	5432	5670	5680	5575
	$ZnSO_4$	25	6120	6170	6220	6266	6194
		50	6167	6174	6294	6326	6240
		100	6200	6124	6100	6200	6156
		Mean	6155	6156	6204	6264	
	Zn Chelate	5	6141	6320	6440	6816	6429
Soil application + Foliar spraying of 0.5 % $ZnSO_4$ thrice		25	6461	6426	6600	6532	6504
		50	6640	6530	6746	6636	6638
		100	6640	6722	6832	6740	6736
		Mean	6580	6559	6726	6636	
	Zn Chelate	5	6730	6800	6646	6730	6726
	Zn EFYM	25	6700	6900	7126	7137	6965
	SE d	CD					
Zn	41.2	82.1					
V	21.5	40.1					
ZnxV	60.1	NS					

Table 3: Effect of Zn mineral fertilization on Straw Yield (kg/ha) of Rice genotypes (Kharif).

Zn treatments			Genotypes				Mean
Mode of application	Sources	Levels (kg ha^{-1})	CO 47	CO 51	ADT 37	ADT 47	
Soil Application	No Zn	0	5911	6011	5750	5645	5829
	$ZnSO_4$	25	6423	6456	6203	6165	6311
		50	6607	6859	6378	6387	6432
		100	6369	6457	6465	6547	6459
		Mean	6327	6445	6199	6186	
	Zn Chelate	5	6200	6347	6075	6109	6182
Soil application + Foliar spraying of 0.5 % $ZnSO_4$ thrice		25	6533	6766	6413	6375	6521
		50	6517	6765	6425	6606	6578
		100	6270	6601	6398	6269	6384
		Mean	6515	6657	6290	6276	
	Zn Chelate	5	6345	6547	6178	6299	6342
	Zn EFYM	25	7350	7460	7265	6912	7246
	SE d	CD					
Zn	42.2	84.5					
V	22.3	44.5					
ZnxV	63.1	120.1					

Table 4: Effect of Zn mineral fertilization on Straw Yield (kg/ha) of Rice genotypes (Rabi).

the four genotypes, CO 51 recorded higher Zn uptake (305 g/ha) followed by CO 47 (278 g/ha) followed by ADT 47 rand ADT 37. The result reveals that application of FYM increased yield parameters as compare to control (no FYM). Similarly [13] reported that might be due to its successive decomposition that enabled the wheat crop to ensure an almost continuous supply of nutrients efficiently throughout the growth period of crop and along with it is also improved the physical, chemical and biological properties of soil. The results are in line with the findings of [11] reported that the treatment combination of 100% NPK + 10 kg Zn ha^{-1} was found to have a higher concentration of DTPA-extractable Zn. The findings of the research were in harmony with the results of [6,12,20]. The straw Zn uptake was generally higher when compared to the grain Zn uptake in both Kharif and Rabi seasons similar findings was obtained by [1] reported that zinc concentration as well as uptake was greater in the shoot as compared with concentration and uptake in the grain. From the results it was concluded that, among the genotypes, Co 51 recorded higher yield followed by Co 47 followed by ADT 47 and ADT 37. And also the application of 25 kg $ZnSO_4$ as enriched FYM + 0.5% $ZnSO_4$ foliar spray thrice recorded higher yield Zn content and Zn uptake.

Zn treatments			Genotypes				Mean
Mode of application	**Sources**	**Levels (kg ha^{-1})**	**CO 47**	**CO 51**	**ADT 37**	**ADT 47**	
Soil Application	No Zn	0	18.0	18.5	17.1	17.4	17.7
	$ZnSO_4$	25	24.5	25.3	22.5	23.5	23.9
		50	26.3	27.3	24.6	25.3	25.8
		100	25.0	26.5	23.9	24.0	24.8
		Mean	24.5	25.6	22.9	23.5	
	Zn Chelate	5	24.0	24.3	23.0	22.3	23.4
Soil application + Foliar spraying of 0.5 % $ZnSO_4$ thrice		25	24.5	25.2	24.0	23.0	24.3
		50	25.4	26.4	25.3	24.5	30.3
		100	24.4	24.3	23.5	22.2	23.6
		Mean	24.7	25.3	24.2	23.2	
	Zn Chelate	5	24.9	25.4	23.5	23.1	24.2
	Zn EFYM	25	38.5	39.5	37.0	37.8	38.2
	SE d	CD					
Zn	0.37	0.79					
V	0.6	0.32					
ZnxV	1.2	2.4					

Table 5: Effect of Zn mineral fertilization on Grain Zn content (ppm) of rice genotypes (Kharif).

Zn treatments			Genotypes				Mean
Mode of application	**Sources**	**Levels (kg ha^{-1})**	**CO 47**	**CO 51**	**ADT 37**	**ADT 47**	
Soil Application	No Zn	0	18	18	19	19	18.5
	$ZnSO_4$	25	21.4	22.4	23.4	24.2	22.8
		50	23.5	24.2	25.2	26.2	24.7
		100	23.9	24.0	25.0	26.5	24.8
		Mean	22.9	23.5	24.5	25.6	
	Zn Chelate	5	32.3	33.0	34.0	34.3	25.3
Soil application + Foliar spraying of 0.5 % $ZnSO_4$ thrice		25	33.0	34.0	34.5	35.2	34.1
		50	34.5	35.0	35.4	36.4	35.3
		100	32.2	33.5	34.0	34.3	33.5
		Mean	33.2	34.1	34.6	35.3	

	Zn Chelate	5	33.0	33.5	34.9	35.4	34.2
	Zn EFYM	25	40.5	40.5	41.5	42.5	41.2
	SE d	CD					
Zn	0.35	0.77					
V	0.20	0.42					
ZnxV	0.44	NS					

Table 6: Effect of Zn mineral fertilization on Grain Zn content (ppm) of rice genotypes (Rabi).

Zn treatments			Genotypes				Mean
Mode of application	**Sources**	**Levels (kg ha^{-1})**	**CO 47**	**CO 51**	**ADT 37**	**ADT 47**	
Soil Application	No Zn	0	82	81	92	92	86
	$ZnSO_4$	25	109	115	121	126	117
		50	121	124	133	139	129
		100	122	120	126	138	126
		Mean	117	120	127	135	
	Zn Chelate	5	169	175	188	198	182
Soil application + Foliar spraying of 0.5 % $ZnSO_4$ thrice		25	183	192	195	201	192
		50	194	200	205	212	202
		100	178	189	195	197	199
		Mean	185	194	199	204	
	Zn Chelate	5	185	193	202	205	196
	Zn EFYM	25	238	238	259	265	250
	SE d	CD					
Zn	3.2	6.4					
V	6.6	13.5					
ZnxV	11.2	NS					

Table 7: Effect of Zn mineral fertilization on Grain Zn uptake (g/ha) of rice genotypes (Kharif).

Zn treatments			Genotypes				Mean
Mode of application	**Sources**	**Levels (kg ha^{-1})**	**CO 47**	**CO 51**	**ADT 37**	**ADT 47**	
Soil Application	No Zn	0	88	90	79	80	84
	$ZnSO_4$	25	130	135	117	121	126
		50	139	149	129	133	138
		100	129	141	125	123	130
		Mean	121	129	113	114	
	Zn Chelate	5	122	125	116	117	120
Soil application + Foliar spraying of 0.5 % $ZnSO_4$ thrice		25	130	135	125	119	127
		50	135	146	134	132	137
		100	126	131	124	114	124
		Mean	130	137	128	122	
	Zn Chelate	5	128	133	119	117	100
	Zn EFYM	25	240	259	217	226	235

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	SE d	CD					
Zn	3.8	7.6					
V	7.6	14.5					
ZnxV	4.8	9.6					

Table 8: Effect of Zn mineral fertilization on Grain Zn uptake (g/ha) of rice genotypes (Rabi).

Zn treatments			**Genotypes**				
Mode of application	**Sources**	**Levels (kg ha^{-1})**	**CO 47**	**CO 51**	**ADT 37**	**ADT 47**	**Mean**
Soil Application	No Zn	0	154	159	177	182	168
	ZnSO$_4$	25	183	191	207	206	196
		50	191	198	214	214	204
		100	195	201	213	212	205
		Mean	189	196	211	211	
	Zn Chelate	5	223	233	253	265	243
Soil application + Foliar spraying of 0.5 % ZnSO$_4$ thrice		25	238	238	267	269	253
		50	245	247	281	278	262
		100	251	255	288	289	270
		Mean	244	246	278	278	
	Zn Chelate	5	249	254	266	290	264
	Zn EFYM	25	328	340	360	365	348
	SE d	CD					
Zn	4.8	9.7					
V	2.2	4.5					
ZnxV	12.2	NS					

Table 9: Effect of Zn mineral fertilization on Straw Zn uptake (g/ha) of rice genotypes (Kharif).

Zn treatments			**Genotypes**				
Mode of application	**Sources**	**Levels (kg ha^{-1})**	**CO 47**	**CO 51**	**ADT 37**	**ADT 47**	**Mean**
Soil Application	No Zn	0	165	174	155	155	162
	ZnSO$_4$	25	202	209	182	188	195
		50	213	235	207	212	216
		100	191	203	188	189	192
		Mean	192	205	183	186	
	Zn Chelate	5	210	218	200	204	208
Soil application + Foliar spraying of 0.5 % ZnSO$_4$ thrice		25	261	311	218	229	254
		50	295	313	291	293	298
		100	278	292	278	264	278
		Mean	278	305	262	262	
	Zn Chelate	5	221	231	209	208	217
	Zn EFYM	25	336	370	341	337	346
	SE d	CD					
Zn	4.2	9.7					

V	3.6	6.7					
ZnxV	11.2	4.2					

Table 10: Effect of Zn mineral fertilization on Straw Zn uptake (g/ha) of rice genotypes (Kharif).

Declarations

- The author have no relevant financial or non-financial interests to disclose.
- The author have no competing interests to declare that are relevant to the content of this article.
- The author certify that they have no affiliations with or involvement in any organization or entity with any financial interest or non-financial interest in the subject matter or materials discussed in this manuscript.
- The author have no financial or proprietary interests in any material discussed in this article.

Bibliography

1. Fageria NK., *et al.* "Zinc nutrition of lowland rice". *Communications in Soil Science and Plant Analysis* 42 (2011): 1719-1727.

2. Gupta VK and Kala R. "Response of paddy to Zinc application and its effect on Zn, Cu, Mn and Fe concentration and uptake". *Journal of Agronomy* 8 (1992): 81-84.

3. Humphries EC. "Mineral components and ash analysis". In *Modern Methods of Plant Analysis.* Springer verlag publication, Berlin (1956).

4. Impa SM and Johnson-Beebout SE. "Mitigating zinc deficiency and achieving high grain Zn in rice through integration of soil chemistry and plant physiology research". *Plant Soil* 361 (2012): 3-41.

5. Jackson Ml. "Soil chemical Analysis". Pentice Hall of India Pvt. Ltd., New Delhi, India (1973).

6. Jena PK., *et al.* "Effect of zinc management practices on growth, yield and economics in rice". *Crop Production* 43 (2006): 326-328.

7. Jena PK., *et al.* "Effect of zinc management practices on growth, yield and economics in transplanted rice". *Oryza* 43 (2006): 326-328.

8. Kalyanasundaram D and Surendra Kumar PS. "Integrated nutrient management in hybrid rice Effect of Zn and Fe aplication on nutrient content". *Advances in Plant Sciences* 16 (2003): 171-175.

9. Kanhaiya Lal R and JanardanY. "Influence of PGPR and Zinc Enriched FYM on Growth and Yield of Rice at Different Levels of Phosphors in an Inceptisol of Varanasi". *International Journal of Current Microbiology and Applied Sciences* 6 (2017): 1453-1464.

10. Khampuang K., *et al.* "Foliar zinc application improved grain zinc accumulation and bioavailable zinc in unpolished and polished rice". *Plant Production Science* 24.1 (2021): 94-102.

11. Kumar V and Singh AP. "Long-term effect of green manuring and farmyard manure on yield and soil fertility status in rice-wheat cropping system". *Journal of the Indian Society of Soil Science* 58 (2010): 409-412.

12. Meena MC., *et al.* "Effect of Zn and Fe enriched FYM on mustard yield and micronutrients availability in loamy sand soil (Typic Haplustept) of Anand". *Journal of the Indian Society of Soil Science* 54 (2006): 495-499.

13. Patil RB and Varade PA. "Microbial population in rhizosphere as influenced by high input rates of fertilizer application to sorghum on a Vertisol". *Journal of the Indian Society of Soil Science* 46 (1998): 223-227.

14. Peda Babu P., *et al.* "Effect of zinc on rice in rice –black gram cropping system in saline soils". *The Andhra Agricultural Journal* 54 (2007): 47-50.

15. Rana WK and Kashif SR. "Effect of different Zinc sources and methods of application on rice yield and nutrients concentration in rice grain and straw". *Journal of Environmental and Agricultural Sciences (JEAS) ISSN* 2313 (2013): 8629.

16. Rehman HU., *et al.* "Zinc nutrition in rice production systems: a review". *Plant Soil* 361 (2012): 203-226.

17. Rehman MT., *et al.* "Effect of sulphur and zinc on growth, yield and nutrient uptake of boro rice". *Journal of Soil and Nature* 2 (2008): 10-15.

18. Sachdev P., *et al.* "Effect of varying levels of zinc and manganese on dry matter yield and mineral composition of wheat plant at maturity". *Journal of Nuclear Agriculture and Biology* 17 (1988): 137-143.

19. Singh VP and Sharma YK. “Phosphorus and zinc requirement of rice under saline condition”. *International Journal of Bio-resource and Stress Management* 5 (2014): 395-399.

20. Sudhakar PC., *et al.* “Effect of graded fertility levels and silicon sources on crop yield, uptake and nutrient-use efficiency in rice (Oryza sativa)”. *Indian Journal of Agronomy* 51 (2006): 186-188.

21. Waleed KR., *et al.* “Effect of different Zinc sources and methods of application on rice yield and nutrients concentration in rice grain and straw”. *Journal of Agriculture and Environmental Sciences* 1 (2014): 9.

22. Walkley A and CA Black. “An estimation of different methods for determining soil organic matter and a proposed modification of the chromic acid titration method”. *Soil science* 37 (1934): 29-38.

23. Zhao FJ and Mcgrath SP. “Biofortification and phytoremediation”. *Current Opinion in Plant Biology* 12 (2009): 373-380.