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EFFECT OF ZINC FERTILIZATION ON YIELD AND ZINC UPTAKE EFFICIENCY OF RICE GENOTYPES GROWN IN CENTRAL INDIA

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Abstract- A field experiment was conducted during *Kharif* 2009 under AICRP of MSN at experimental farm of Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidhyalya, Jabalpur, Madhya Pradesh, India to find out high yielding and zinc efficient genotypes of rice in a Vertisols. The results revealed that the application of zinc @ 20 kg Zn ha^{-1} as basal +0.5% foliar spray of $ZnSO_4$ was found positive and significant influence on grain yield (4.96 t ha^{-1}) and Zn uptake (384.91 g ha^{-1}) over control (4.04 t ha^{-1}). Among the genotypes, the MTU-1010 was found superior in respect of grain yield (5.44 t ha^{-1}).The highest uptake of Zn recorded by Kranti (350.35 g ha^{-1}) but Swarna recorded the lowest (199.72 g ha^{-1}). However, the cultivar 'Shyamla' recorded the highest yield as well as uptake efficiency index and found genetically efficient cultivar, while MTU-1010 was found as genetically inefficient and agronomically highly efficient cultivar.

Keywords- Zn uptake, efficiency index, Zn efficient, Rice genotypes, Yield, Zn levels

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Introduction

Rice (*Oryza sativa* L.) is an important cereal crop of the world and extensively cultivated food crop, which provides half the daily food for one of every three persons on the earth. In India, rice is cultivated in 44.01 million ha area with 105.30 million tonnes production and an average productivity of 23.93 q ha^{-1} [1]. To meet the demands of increasing population and to maintain self-sufficiency, the present production level needs to be increased up to 120 million tonnes by the year 2020 [2]. The average productivity of rice in Madhya Pradesh is lower that needs further increased to feed ever-increasing population. Over the year's traditional rice varieties were replaced by modern high yielding varieties that removed large quantities of zinc and use of excessive phosphatic fertilizer have resulted in depletion of available Zn from the soil. There are different approaches to alleviate Zn deficiency including application of fertilizers containing Zn. Soil application of Zn fertilizers seems to be a useful approach for increasing grain yield of cereals (20-50%) under Zn-deficient conditions; however, in soils with high pH, soil-applied Zn will become less available for plant uptake due to soil fixation [3]. About 60 percent soils sample of Madhya Pradesh and 44% soils of India are deficient in Zn [4]. Zn is important for soil-plant-animal and human continuum [5]. However, zinc deficiency in rice has been widely reported in many rice-growing regions of the world. Zn deficiency in crop plants reduces the yield and cause malnutrition in humans, where a high proportion of rice is consumed as a staple food [6].

In most soils, total Zn is much larger than the amount of removed by a crop [7] but the ability to absorb sufficient Zn from soil is a concern. High costs of Zn fertilizers and its repeated and relatively low-efficient application may be sufficient justification for use of efficient rice genotypes that can grow well on soils with low amounts of available Zn [8].Productivity of rice depends upon balance application of nutrients. Farmer's of state having the apathy to use micronutrients in their farming system resulting into poor micronutrients soils [9]. Biofortification of staple food crops is a feasible, sustainable, and economical approach to defeat zinc malnutrition in the population depending on the origin of plant in the diet. Realizing the importance of zinc efficient genotypes and biofortification to increases the zinc density in plant grain and at the same time seriousness of its deficiency in soils and plants, the present study was undertaken.

Materials and Methods

A field experiment was conducted during *Kharif* 2009 under All India Co-ordinated Research Project on Micro, Secondary Nutrients, Pollutants Elements in Soil and Plants, of Department of Soil Science and Agricultural Chemistry, Jawaharlal Nehru Krishi Vishwa Vidhyalya, Jabalpur, Madhya Pradesh, India to find out the suitable genotype for Zn deficient soil condition and to optimize the dose of Zn for sustainable production of rice. The soil of experimental site was clayey (*Typic Haplustert*), having pH 7.8, organic carbon 5.7 g kg^{-1} (medium) available N 250 kg ha^{-1} [10], P 12 kg ha^{-1} [11] and K 480 kg ha^{-1} [12] and low in diethylene triamine penta acetic acid-triethanolamine (DTPA-TEA) extractable Zn 0.51 mg kg^{-1} (low) [13].

Treatments comprised of twenty rice varieties *viz*., Chandra Hasini, Pusa Basmati, Safari-17, Swarna, Purnima, Danteshwari, Indira Sona, Indira Sugandhit Dhan-1, IR-36, Bamleshwari, Samleshwari, Dubraj, Mahamaya, PKV-HMT, Shyamla, MTU-1010, Vandana, Kranti, Madhuri and Karma Masuri and five levels of Zn *viz*., 0.0, 10, 20, 20 kg Zn +0.5% spray of $ZnSO_4$ and 0.5% spray of $ZnSO_4$. The treatments were replicated thrice in a factorial randomized block design. The Zn levels were applied through zinc sulphate along with basal dose of 60 N, 80 P_2O_5 and 40 K_2O kg ha^{-1}. The seed was sown @ 100 kg ha^{-1} in line of 22.5 cm row to row distance on 15.07.2009. The remaining 60 kg N was applied equally at maximum tillering stage and flowering. The spray of 0.5 % $ZnSO_4$ + 0.25% of lime were applied at tillering and flag leaf stage.

Chemical analysis of Zn in plant samples

The crop was harvested at maturity and grain and straw yield were recorded after sun drying of varieties. The concentration of zinc in grain and straw was estimated using AAS by following standard procedures. One gram of powdered oven dried plant material (60-70 ˚C) was taken in 100 ml conical flask and 10 ml of di-acid mixture (10:4 of HNO_3-$HClO_4$) was added in the flask and mixed by swirling. The flask was placed on hot plate in a digestion chamber. After cooling, the digested was transferred to a 50 ml volumetric flask composed of ultrapure water and then filtered. The contents were further evaporated until the volume was reduced to 3 to 5 ml but not to dryness. The completion of digestion was confirmed when the liquid become colorless. After cooling the flask, 20 ml of glass double distilled water was added. The volume was made up to 50 ml with glass double distilled water and filtered the solution using what man No. 41 filter paper. The filtrate was used for estimation of zinc by AAS.

Zn use efficiencies

Agronomic efficiency (AE) (kg grain increased kg^{-1} Zn applied)=$(Y_{Zn}-Y_{Pu})/Zn_a$ and recovery efficiency (% of Zn taken up by a crop) (RE)=$[(U_{Zn}-U_{Pu})/Zn_a]\times100$ of applied Zn were computed. Where in, Y_{Zn} and U_{Zn} refer to the grain yield (kg ha$^{-1)}$ and total Zn uptake (kg ha^{-1}), respectively, of rice in Zn applied plots; Y_{Pu} and U_{Pu} refer to the grain yield (kg ha^{-1}) and total Zn uptake (kg ha$^{-1),}$ respectively, of rice in PU (no Zn) applied plots; Zn_a refers to the Zn applied (kg ha^{-1}).

Yield and Zn uptake efficiencies index

A genotype having a high grain yield efficiency index has the ability to produce a relatively high yield under Zn-limited soil conditions compared with its own yield under Zn-sufficient conditions and with yields of other genotypes tested. This agronomic definition is meaningful to a plant breeder for selecting genetic material of cereals in the field. Zinc uptake was estimated by multiplying the yield and concentration of zinc. Further, yield efficiency index and uptake efficiency index were determined using the following formula. The genotypes were categorized into Zn-efficient and Zn-inefficient groups based on grain yield and Zn uptake efficiency indices.

Yield efficiency index= (Total yield in control plots/Total yield in treated plots)X100

Uptake efficiency index= (Total uptake in control plots/ Total uptake in treated plots)X100

Statistical analysis

The data on observation made were analyzed statistically by applying the technique of factorial randomized block design taken from [14]. Critical difference for examining significance was calculated at p=0.05

Results and Discussion

Yield response

The data presented in [Table-1] showed that the grain yield of rice varieties varied from 3.44 to to 5.44 and straw yield varied from 4.51 to 7.78 t ha^{-1}. The maximum grain and straw yield were recorded by MTU-1010 (5.44 and 7.78 t ha^{-1}) followed by Madhuri (5.3 and 6.38 t ha^{-1}), Bamleshwari (5.25 and 7.01 t ha^{-1}) and Kranti (5.21 and 7.04 t ha^{-1}) but the genotype Swarna recorded the lowest grain and straw yield (3.44 and 4.51 t ha^{-1}), respectively. All the varieties were found significantly superior to Swarna for grain yield except Indira Sona. The varieties ISD-1, Dubraj and Mahamaya were found on par with Indira Sona for grain yield. Though the varieties Chandra Hasini, Pusa Basmati, Safari-17, Purnima, Danteshwari, IR-36, Bamleshwari, PKV-HMT, MTU-1010, Samleshwari, Shyamla, Vanadana, Kranti Madhuri and Karma Masuri were found significantly superior to Indira Sona but Chandra Hasini, Pusa Basmati, Purnima, Samleshwari, Shyamla, Vanadana and Karma Masuri were found on a par amongst themselves for grain yield. Safari-17 and Danteshwari variety were also found significantly superior to ISD-1, Dubraj and Mahamaya but the difference between the two variety was found non significant. However, the varieties Bamleshwari, MTU-1010, Kranti and Madhuri were found significantly superior to all remaining varieties but the varieties were found on par amongst themselves. All the varieties were found significantly superior to, Swarna for straw yield except Pusa Basmati, Dubraj and PKV-HMT, which were found on par. The variety Safari-17 (7.93 t ha^{-1}) and MTU-1010 (7.78 t ha^{-1}) produced significantly higher straw yield than all other varieties except Samleshwari. These varieties might be more responsive to the production factors than other varieties. Application of Zn @10, 20, 20+0.5% foliar spray of $ZnSO_4$ and 0.5% foliar spray of $ZnSO_4$ significantly increased the grain and straw yield of rice over control. While the application of Zn @ 10, 20 and 20+0.5% foliar spray of $ZnSO_4$ were also found significantly superior to 0.5% foliar spray of $ZnSO_4$ for grain yield. However, Zn @ 20 kg Zn and 20 kg Zn+0.5% foliar spray of $ZnSO_4$ gave significantly higher grain and straw yield than that of 10 kg Zn ha^{-1} but the levels were found on par. Significant increase in grain and straw yield of these varieties could be attributed to the fact that the optimum utilization of all the production factors accelerates photosynthesis resulting in better growth and yield [15-16]. The results are also in corroboration with the findings of [17-21].

Zn uptake

The Zn uptake by varieties varied from 199.72 g ha^{-1} (Swarna) to 350.35 g ha^{-1} (Kranti). The highest Zn uptake was observed by Kranti (350.35 g ha^{-1}) followed by MTU-1010 (343.95 g ha^{-1}) and Safari-17 (304.31 g ha^{-1}). The variety Kranti and MTU-1010 were found significantly superior to the rest of varieties for Zn uptake but the difference between the two variety was found non significant. The varieties Safari-17 and Bamleshwari were also found significantly superior to Chandra Hasini, Pusa Basmati, Swarna, Purnima, Danteswari, Indira Sona, IR-36, Dubraj, PKV-HMT, ISD-1, Shaymla, Vandana and Madhuri but the difference between the two varieties was found non significant. Safari-17 and Bamleshwari were found on par with Samleshwari and Mahamaya. Similarly, Chandra Hasini, Purnima, Dhanteswari ISD-1, Shyamala, Vandana, Madhuri, Samleshwari and Mahamaya were found significantly superior to Pusa Basmati. The lowest Zn uptake was observed in variety Swarna. The Zn uptake by all the varieties were found significantly superior to Swarna except Dubraj but the varieties Pusa Basmati, Indira Sona, IR-36, PKV-HMT and Karma Masuri were found on par with Dubraj. The increase of zinc uptake might be due to increase in grain and straw yield of rice with zinc application.

Application of Zn @ 10, 20, 20 + 0.5 % $ZnSO_4$ and 0.5% $ZnSO_4$ significantly increased the Zn uptake over control. However, the Zn uptake with 20 kg Zn+0.5% $ZnSO_4$ spray was found significantly superior to 10 and 20 kg Zn and 0.5 % $ZnSO_4$ spray. It increased from 126.60 g ha^{-1}(control) to 384.91 g ha^{-1} with 20 Zn+0.5% $ZnSO_4$ and 0.5% spray of $ZnSO_4$. Uptake of zinc was also significantly increased with foliar application of 0.5% spray of $ZnSO_4$ over 10 kg Zn ha^{-1}. The increase of Zn uptake due to Zn application attributed to Zn supply to more root surface area and the ability to change the chemistry and biology of rhizosphere releasing phytosiderophores from roots, which ultimately increase Zn uptake by the plants. [5, 9-25] also reported similar increase in the uptake of Zn due to Zn application. The interaction between Zn levels and variety was found non-significant.

Selection of Zn efficient rice cultivars

Rice genotypes were categorized under Zn-efficient and Zn inefficient groups using Zn efficiency index-yield and uptake base. Yield efficiency index and Uptake efficiency index values of each cultivar were plotted in scattered diagram depicted in [Fig-1] to find out the efficient as well as inefficient varieties under 20 kg Zn SO_4 treatment in combination with foliar spray.

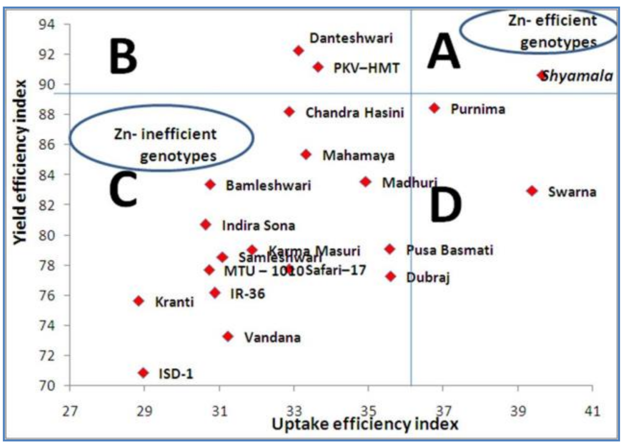

Fig-1 Yield and uptake-efficiencies index of different rice varieties

Table-1 *Effect of rice genotypes and Zn levels on grain and straw yield and total Zn uptake by rice*

	Grain Yield (t ha⁻¹)						Straw Yield (t ha⁻¹)						Zn Uptake (g ha⁻¹)					
Genotypes/Zn levels (kg ha⁻¹)	0Zn	10 Zn	20 Zn	20 Zn+ 0.5% $ZnSO_4$	0.5% $ZnSO_4$ Spray	Mean	0 Zn	10 Zn	20 Zn	20 Zn +0.5% $ZnSO_4$	0.5% $ZnSO_4$ Spray	Mean	0 Zn	10 Zn	20 Zn	20 Zn +0.5% $ZnSO_4$	0.5% $ZnSO_4$ Spray	Mean
Chandra Hasini	4.19	4.31	4.63	4.75	4.22	4.42	6.46	6.11	7.05	7.51	6.18	6.66	134.71	212.51	330.67	409.79	291.8	275.9
Pusa Basmati	3.93	4.44	4.82	4.97	4.02	4.44	4.30	4.72	5.08	5.03	4.56	4.74	111.48	197.79	283.06	313.38	228.88	226.91
Safari -17	3.99	4.45	5.07	5.13	4.04	4.53	6.55	8.18	8.84	8.36	7.75	7.93	144.06	240.76	373.99	438.11	324.62	304.31
Swarna	3.11	3.48	3.65	3.75	3.23	3.44	4.31	4.64	5.03	5.21	3.37	4.51	113.13	183.13	249.83	287.24	165.28	199.72
Purnima	3.90	4.12	4.38	4.41	4.00	4.16	5.37	5.62	6.13	6.60	5.70	5.88	141.95	241.49	310.26	386.06	279.11	271.78
Danteshwari	4.51	4.80	4.89	4.89	4.57	4.73	6.39	6.16	7.34	7.71	7.11	6.94	132.24	223.12	327.76	399.27	298.88	276.25
Indira Sona	3.26	3.65	4.00	4.04	3.38	3.67	5.12	5.46	6.39	6.41	5.47	5.77	103.91	193.18	295.45	339.06	243.88	235.1
Indira Sugandhit Dhan –1	3.36	4.05	4.66	4.74	3.54	4.07	4.94	6.05	6.99	7.04	6.45	6.29	113.43	232.88	338.10	391.58	295.6	274.32
IR – 36	4.44	5.07	5.79	5.83	4.69	5.16	4.36	5.27	6.21	5.99	4.57	5.28	109.70	210.52	307.09	355.06	213.16	239.11
Bamleshwari	4.81	5.23	5.63	5.77	4.95	5.28	5.82	6.86	7.31	7.99	7.06	7.01	140.33	243.79	369.59	456.24	351.01	312.19
Samleshwari	3.74	4.32	4.74	4.76	3.83	4.28	6.26	7.77	8.06	7.92	7.19	7.44	121.65	272.93	357.29	391.21	299.88	288.59
Dubraj	3.50	4.00	4.38	4.53	3.60	4.00	4.60	5.03	5.37	5.73	4.82	5.11	112.09	194.73	271.12	314.94	234	225.38
Mahamaya	3.67	4.12	4.37	4.30	3.86	4.06	5.96	6.53	7.21	7.58	6.35	6.72	134.48	260.74	340.16	403.58	302.37	288.27
PKV–HMT	4.43	4.68	4.83	4.86	4.51	4.66	4.29	3.96	5.14	5.41	4.50	4.66	115.96	193.06	296.91	344.56	250.54	240.21
Shyamla	4.15	4.33	4.50	4.58	4.23	4.36	5.30	5.29	5.97	6.34	5.76	5.73	141.04	232.34	325.36	355.71	296.99	270.29
MTU–1010	4.81	5.13	6.12	6.19	4.93	5.44	6.98	7.35	8.27	8.76	7.56	7.78	151.32	274.87	415.71	492.44	385.4	343.95
Vandana	3.81	4.32	4.94	5.20	3.87	4.43	6.21	6.96	7.45	7.27	6.24	6.83	119.78	217.13	347.02	383.44	255.33	264.54
Kranti	4.47	5.12	5.86	5.91	4.68	5.21	6.57	6.95	7.38	7.52	6.80	7.04	142.86	297.52	429.65	495.33	386.4	350.35
Madhuri	4.82	5.27	5.69	5.77	4.97	5.30	5.70	6.43	7.09	6.81	5.86	6.38	132.96	242.08	344.45	380.65	272.31	274.49
Karma Masuri	3.84	4.39	4.79	4.86	3.91	4.36	4.70	5.29	6.23	6.36	5.34	5.58	114.99	215.95	306.19	360.58	250.63	249.67
Mean	4.04	4.46	4.89	4.96	4.15		5.51	6.03	6.73	6.88	5.93		126.60	229.03	330.98	384.91	281.3	
Level of Significance	**SEm±**			**CD(p=0.05)**			**SEm±**			**CD(p=0.05)**						**SEm±**	**CD(p=0.05)**	
(i) Zn	**0.03**			**0.09**			**0.12**			**0.35**						**4.7**	**13.13**	
(ii) Variety	**0.16**			**0.45**			**0.23**			**0.64**						**9.35**	**26.1**	
(iii)Zn*Variety	**0.15**			**NS**			**0.56**			**NS**						**21.3**	**NS**	

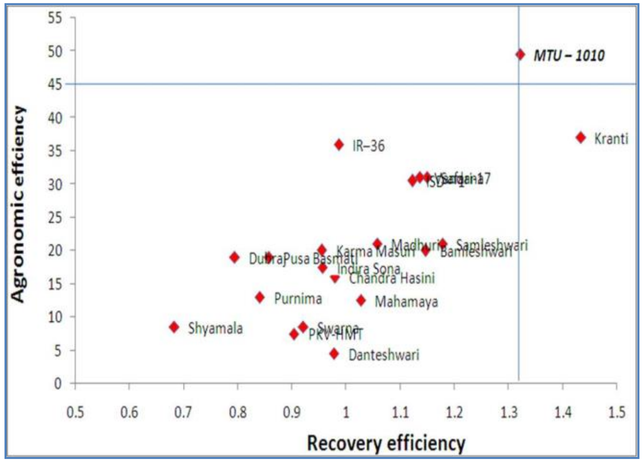

Fig-2 Zn use-efficiencies of different rice varieties

The Shyamala cultivar having high yield as well as uptake efficiency index was fall in quadrant A as depicted in scattered diagram and defined genetically efficient cultivar, while reverse of this fall in quadrant C and defined as genetically-inefficient cultivars. Interestingly, the genetically inefficient cultivars were agronomically highly efficient [Fig-2]. Thus, the efficient cultivars may be utilized by breeder for QTL (Quantative traits loci) identification and developing high yielding zinc enriched cultivars (genetic biofortification) while the inefficient cultivars may be used for agronomic biofortification to dense the grains of highly responsive cultivars with Zn. The present study emphasized that the genotypes provided highest yield along with Zn uptake. Cultivation of the variety with 20 kg Zn levels +0.5 % offers good scope for better livelihood opportunity and nutritional security.

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Conflict of Interest: None declared

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