Oryza Vol. 53 No.1, 2016 (42-47)

Efficiency of rice cultivars for zinc bio-fortification under red and lateritic soil condition

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Received : 08 October 2015 Accepted : 16 March 2016 Published : 15 June 2016

ABSTRACT

Zinc acquisition, utilization and efficiency in red lateritic soil condition (2.66 mg kg^{-1} DTPA extractable Zn) were studied in 25 selected rice cultivars. Results suggested that medium duration rice cultivars produced higher grain yield (66.74 q ha^{-1}) followed by late (57.35 q ha^{-1}) and early (30.01 q ha^{-1}) duration. Zinc content was found 32.11, 31.75 and 28.75 mg kg^{-1} in paddy grains, which were 8.48, 15.66 and 10.28 per cent higher to its initial Zn content, respectively. Content of Zn in brown rice of medium duration rice cultivars were found significantly lower. BD-101an early maturity rice cultivars accumulated higher Zn, while Karhani-1, 2 and 3 (medium duration) showed better efficiency of Zn accumulation. Samba Mansuri in series of late maturity rice cultivars accumulated more Zn (42.67 mg kg^{-1}) with application of 100 kg $ZnSO_4.7H_2O$ in soil. In general late and medium duration rice cultivars exhausted>1.00 kg ha^{-1}Zn as compare to early duration rice cultivars from the soil. Apparent Nutrient Recovery (ANR) of Zn by rice were found higher when Zn was applied as soil + foliar application and considerable build up of Zn was also noticed in post harvest soil.

Key words: *Bio-fortification, znefficiency, red and lateritic, brown rice*

Zinc is an essential micronutrient for plants, animals and human beings (Alloway, 2004). Agricultural intensification during the past few decades, without micronutrients in the fertilizer schedule, has enhanced Zn malnutrition in the Indian population (Rattan *et al*. 2012). Globally about 2 million people are considered to be suffering from Zn deficiency (Muller and Krawinkel, 2005). In developing countries Zn deficiency is more alarming,especially in children and women (WHO, 2002). Grain Zn accumulation mechanisms in rice plants can be grouped into two categories according to the predominant sources of Zn loading: as continued root uptake during the grain filling stage (Jiang et al., 2007) and remobilization of Zn from shoots or roots (Wu *et al.*, 2010).

Rice is one of the most important stable crops and is almost exclusively consumed by human being in whole world. Rice based cropping system is predominant in India (Roy *et al*. 2011) and particularly in tribal populated state of our country (Prasad *et al*. 2013). Rice contains low level of micronutrients especially Zn,although it is an important source of energy for human beings. On this background, it was considered pertinent to assess the zinc acquisition, utilization and efficiency in rice, generally grown by the farmers having different maturity period under in red and lateritic soil condition.

MATERIALS AND METHODS

Twenty five cultivars of rice were selected to study the Zn Bio-fortification efficiency in red and lateritic soil condition of Chotanagpur Plateau (Table 1). All selected cultivars of rice were grouped in early (5), medium (13) and late (7) duration of maturity period and experiment was conducted at Deptt. of Soil Science, BAU experimental plot in strip plot design with 3 replications during wet season 2009. The soil had the following characteristics: pH 4.70, organic carbon 5.4 g kg^{-1}, EC 0.24 dS m^{-1} and DTPA extractable Zn 2.66 mg kg^{-1}. The treatments were comprised of different levels viz. T_1-control, T_2- 100kg ha^{-1} zinc sulphate (soil application), T_3- T_2+3 foliar spray of 0.5% zinc sulphate (1st at pre flowering stage, 2nd at heading and 3rd at milking stage). Recommended dose of NPK (100:60:40) were applied. Full dose of P and K and half dose of N were applied before transplanting and remaining dose of N was applied in 2 equal splits. Recommended agronomic practices were followed. After harvesting of rice, yield data and grain straw samples were collected. Brown rice was separated by hand mill and all collected plant materials were processed following standard procedure of washing, drying and grinding. Digestion was carried out following the standard procedure (Piper, 1966). Total Zn content in grain and straw of rice and in soil (Lindsay and Norvell, 1978) were determined with the help of Atomic Absorption Spectrophotometer (ECIL4141). The apparent nutrient recovery (ANR) percentage was calculated by the following formula (Craswell, 1987).

$$\text{ANR}\ (\%) = \frac{\text{A-B}}{\text{C}}\ \text{X}\ 100$$

Where

A= Nutrient uptake in fertilized plot (Kg ha^{-1})

B= Nutrient uptake in unfertilized (Control) Plot (kg ha^{-1})

C= Quantity of nutrient applied (kg ha^{-1})

RESULTS AND DISCUSSIONS

Grain and straw yield : Zinc application showed statistically non-significant ($p<0.05$) effect on grain and straw yield, while rice cultivars exhibited significant response on grain and straw yield of rice in acidic soil condition. Rice cultivars of medium duration (111-135 days) maturity period showed higher grain yield (66.74 q ha^{-1}) followed by late (57.35 q ha^{-1}) and early (30.01 q ha^{-1}) cultivars of rice. Reduction in grain yield of rice in longer duration (>135 days) cultivars were mainly

Table 1. Initial Zn content (mg kg^{-1}) in selected rice cultivars of different maturity period for the experiment

Maturity period	Cultivar	Duration of Maturity (days)	Initial Zn content (mg kg^{-1})
Early duration	BVD 110	90	30.25
	SATHI	105	28.31
	VANDANA	90	25.05
	BD 108	80	31.12
	BD 101	85	33.29
Mean Zn content in early duration of rice			29.60
Medium duration	PUSA RH-10	125	21.21
	KARHAINI 3	115	31.45
	AKSHAY DHAN	135	21.09
	BVD 203	125	28.10
	IR-64	125	25.26
	KARHAINI- 2	115	34.94
	SAMPADA	135	27.52
	MTU 1010	125	27.16
	NAVEEN	125	21.80
	LALAT	125	26.81
	KARHAINI- 1	115	33.15
	PUSA BASMATI	135	28.33
	SURUCHI	120	30.00
Mean Zn content in medium duration of rice			27.45
Late duration	BR- 9	140	22.02
	BHARI DHAN	145	23.13
	DOUBLE GRAIN	145	24.11
	BR- 10	140	26.92
	SWARNA	145	31.09
	IMP. SAMPA MANSURI	145	24.06
	ARIZE 6444	140	31.16
Mean Zn content in late duration of rice			26.07

due to early cessation of soil moisture in sandy loam soil after monsoon season. Straw yield of rice were observed in an increasing trend (70.73 to 137.70 g ha^{-1}) and significantly affected due to maturity period and its interaction with Zn application level (Table 2). Maharana et al. (1993) and Dutta and Rahman (1987) also reported an increase in grain and straw yield of rice with Zn application.

Content of zinc in paddy grain, straw and brown rice: Crop duration significantly affected the content of Zn in paddy grain. Zinc content 32.11, 31.75 and 28.75 mg kg^{-1} were found in early, late and in medium duration rice cultivars, while initial Zn content of 29.60, 27.45 and 26.07 mg $kg^{-1}$was observed respectively in same group of rice grain.Results indicated that in respect to initial Zn content in rice cultivars 8.48, 15.66 and 10.28 per cent Zn content were increased after fortification in red and lateritic soil condition. Content of Zn was higher in paddy grain of all three group of maturity period after 100 kg $ZnSO_4.7H_2O$ + 3foliar application of 0.5% $ZnSO_4.7H_2O$. Similar trend of Zn content were also observed in paddy straw and higher Zn content 76.82 mg $kg^{-1}$was found in straw of early duration rice cultivars (Table 3).

Varietal differentiation and its interaction with Zn application strategy significantly affected the Zn content in brown rice. Zinc content in brown rice was higher (28.00 mg kg^{-1}) in long duration rice cultivars followed by early (26.94 mg kg^{-1}) and medium duration cultivars of rice where no Zn was applied.An increasing trend of Zn content was observed with increasing doses of Zn application (Table 4). Content of Zn in brown rice of medium duration rice cultivars was found significantly lower than that of early and long duration rice cultivars.

The results clearly indicated that transfer factor of Zn from paddy grain to brown rice is significantly correlated to Zncontent in paddy grains. Zinc transfer was found more in brown rice,whereas Zn content was higher in paddy grains in all the three group of rice maturity period.

A significant effect of different cultivars of rice was observed on content of Zn in brown rice. Zinc application showed a non significant effect, while its interaction with rice cultivars was significant for the

Table 2. Grain and Straw yield (q ha^{-1}) of rice cultivars as affected by zinc application of different maturity period of rice under red and lateritic soil condition

Maturity Period	Grain				Straw			
	F1	F2	F3	Mean	F1	F2	F3	Mean
80-110 Days (5)	30.57	29.71	30.01	30.10	61.43	66.03	84.72	70.73
111-135 Days (13)	64.95	66.83	68.44	66.74	126.44	119.60	125.77	123.94
> 135 Days (7)	53.17	59.98	58.90	57.35	130.54	25.60	156.96	137.70
Mean	49.56	52.17	52.45	-	106.14	103.74	122.48	-

CD ($P<0.05$) Grain : V - 11.39, Zn - NS, V X Zn - NS
CD ($P<0.05$) Straw : V - 24.00, Zn - NS, V X Zn - 31.54
F_1 - RDF, F_2 - F_1 + 100 Kg $ZnSO_4.7H_2O$ ha^{-1}, F_3 - F_2 + 0.5 % Spray of $ZnSO_4.7H_2O$

Table 3. Content of Zinc (mg kg^{-1}) in paddy Grain and Straw as affected by zinc application of different maturity period of rice under red and lateritic soil condition

Maturity Period	Grain				Straw			
	F1	F2	F3	Mean	F1	F2	F3	Mean
80-110 Days (5)	28.87	31.80	35.67	32.11	49.74	83.07	97.67	76.82
111-135 Days (13)	26.69	27.69	31.87	28.75	40.54	70.51	88.72	66.59
> 135 Days (7)	29.24	30.29	35.71	31.75	35.43	66.43	121.62	74.51
Mean	28.27	29.93	34.42	-	41.90	73.34	102.67	-

CD ($P<0.05$) Grain : V - 2.90, Zn - 1.01, V X Zn - 5.03
CD ($P<0.05$) Straw : V - 15.16, Zn - 3.45, V X Zn - 24.98
F_1 - RDF, F_2 - F_1 + 100 Kg $ZnSO_4.7H_2O$ ha^{-1}, F_3 - F_2 + 0.5 % Spray of $ZnSO_4.7H_2O$

Table 4. Content of Zinc (mg kg^{-1}) in brown rice as affected by zinc application of different maturity period of rice in under red and lateritic soil condition

Category	Zn application			
	F1	F2	F3	Mean
80-110 Days(5)	26.94	31.20	32.07	30.07
111-135 Days(13)	24.36	25.95	27.21	25.85
> 135 Days (7)	28.00	28.95	31.90	29.62
Mean	26.43	28.70	30.39	-

CD (P<0.05) : V - 2.85, Zn - NS, V X Zn - 5.36
F_1 - RDF, F_2 - F_1 + 100 Kg $ZnSO_4.7H_2O$ ha^{-1}, F_3 - F_2 + 0.5 % Spray of $ZnSO_4.7H_2O$

content of Zn in brown rice. Sahay *et al.* (1993), Maharana*et al.* (1993) and Srivastava *et al.* (1999) also observed that additional Zn application increased grain and straw Zn content in rice.Among five early duration selected cultivars of rice, BD 101 accumulated comparatively higher Zn 36.67, 35.33 and 33.00 mg kg $^{-1}$, respectively at 100 kg $ZnSO_4.7H_2O$ with 3 foliar applications of 0.5% $ZnSO_4.7H_2O$, 100 kg $ZnSO_4.7H_2O$ soil application and zero Zn application level (Fig. 1).

Varietal differentiation of Zn content in brown rice was clearly observed among medium duration rice cultivars and content varied from 16.33 (Pusa RH-10 at without Zn application) to 39.33 mg kg^{-1} (Karhani-3 at 100 kg ha^{-1} $ZnSO_4.7H_2O$ with 3 foliar application of 0.5% $ZnSO_4.7H_2O$). In general Karhani-1, 2, and 3 cultivars of medium duration had better efficiency of Zn contentwith and without Zn application in red and lateritic soil of Chottanagpur (Fig. 2).

Among long duration cultivars of rice Samba Mahsuri showed better efficiency as compare to other tested cultivars of rice and accumulated more Zn (42.67mg kg^{-1}) at an application of 100 kg $ZnSO_4.7H_2O$ in soil, while content of Zn in brown rice was observed comparatively lower at the zerolevel of Znapplication (Fig. 3). However, Zn content in grain seed is complex and intricate process comprising of a number of steps starting from its translocation by root to shoots and finally phloem unloading in to developing grain (Welch, 1986). In the past,breeding programme mainly focused on higher yield and resistance to lodging or disease etc.ignoring the improvement of micronutrient concentration in staple food crops (Graham *et al.* 1999, Ortiz-Mohasterio and Graham, 1999). The genotypic variationand maturity period of rice cultivars for differential Zn requirement could serve as a base line for plant breeders who aim at increasing the mineral content of staple food crops through breeding technique.

Total zinc uptake and Apparent Nutrient Recover (ANR): Maximum zinc uptake of 0.675 kg ha^{-1}was recorded by medium duration rice cultivars and was followed by 0.611 and 0.387 kg ha^{-1}, respectively by long and early duration cultivars where Zn was not applied. Zinc uptake was drastically increased with increasing Zn application rate in rice crop. At higher Zn application level (100 kg ha^{-1} $ZnSO_4.7H_2O$ + 3 foliar application of 0.5% $ZnSO_4.7H_2O$) total uptake of 1.906, 1.233 and 0.805 kg ha^{-1}was recorded, respectively in late, medium and early duration groupsof rice cultivars. Total uptake of Znby Imp. Samba Mahsuri and Arize-6444 was recorded as 2.670 and 2.061 kg ha^{-1} in specific situation of abundant Zn availability in acidic soil (Table 5). Most of the medium duration rice cultivars exhausted more than 1.00 kg ha^{-1} Zn except Karhani series of rice cultivars, while early duration rice cultivars

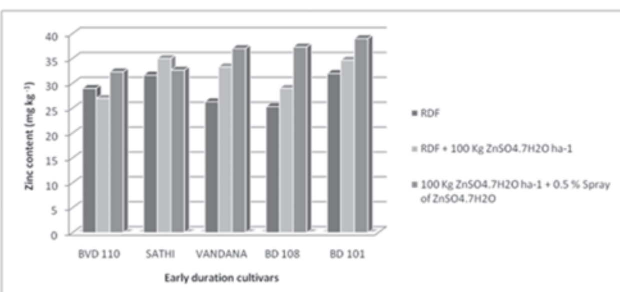

Fig. 1. The content of Zn in early duration cultivars of brown rice

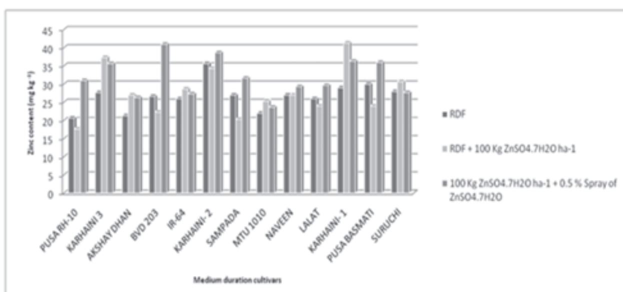

Fig. 2. The content of Zn in medium duration cultivars of brown rice

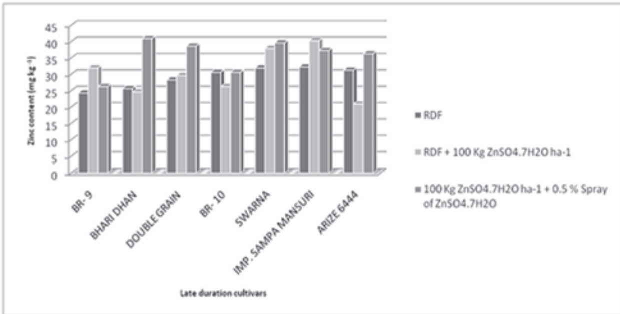

Fig. 3. The content of Zn in late duration cultivars of brown rice

exhaustedless than 1.00kg ha^{-1} Zn from the soil. In general, ANR of Zn by rice cultivars was high when Zn was applied as soil + foliar application. Zinc recovery by rice plant varied from 1.28 (Vandana) to 2.49 (BD-108), 0.452 (Karhani-2) to 1.920 (BVD-203) and 1.461 (BR-9) to 2.670 % (Imp. Samba Mansuri) respectively by early, medium and late duration group of rice cultivars (Table 5).

Zinc content in post harvest soil : DTPA extractable Zn in post harvest soil was observed more than 4.0 mg kg^{-1} when a higher rate of Zn was applied, while in

Table 5. Total Zinc uptake (kg ha^{-1}) by rice (grain + straw) as affected by Zinc application in different maturity period of rice cultivars

Maturity period	Cultivar Fertilizer	RDF (F1)	RDF +100 Kg. $ZnSO_4.7H_2O$ (F2)	ANR in soil application (%)	RDF +100 Kg $ZnSO_4.7H_2O$+3 Spray of 0.5 % $ZnSO_4.7H_2O$ (F3)	ANR in foliar application (%)	MEAN
Early maturity	BVD110	0.480	0.836	1.70	0.944	2.00	0.753
	SATHI	0.435	0.573	0.65	0.761	1.40	0.589
	VANDANA	0.410	0.589	0.85	0.706	1.28	0.568
	BIRSA DHAN108	0.236	0.547	1.48	0.814	2.49	0.532
	BD101	0.375	0.642	1.27	0.798	1.82	0.605
	Mean	0.387	0.637	1.19	0.805	1.80	0.609
Medium maturity	PUSA RH-10	0.755	1.223	2.23	1.651	3.86	1.209
	KARHAINI-3	0.245	0.577	1.58	0.452	0.89	0.424
	AKSHAY DHAN	0.533	0.906	1.77	1.406	3.76	0.948
	BVD203	0.805	1.412	2.89	1.920	4.80	1.379
	IR-64	0.579	0.890	1.48	0.977	1.71	0.815
	KARHAINI-2	0.390	0.498	0.51	0.790	1.72	0.559
	SAMPADA	0.499	0.839	1.62	1.218	3.1	0.852
	MTU1010	1.405	1.330	-0.35	1.443	0.17	1.392
	NAVEEN	1.287	1.105	-0.87	1.902	2.65	1.431
	LALAT	0.813	1.591	3.71	1.543	3.15	1.315
	KARHAINI-1	0.364	0.689	1.55	0.472	0.47	0.508
	PUSA BASMATI	0.548	0.653	0.50	1.060	2.21	0.753
	SURUCHI	0.554	0.875	1.53	1.191	2.74	0.873
	Mean	0.675	0.968	1.40	1.233	2.40	0.958
Late maturity	BR-9	0.715	1.172	2.18	1.461	3.21	1.116
	BHARI DHAN	0.624	0.928	1.45	1.836	5.22	1.129
	DOUBLE GRAIN	0.587	0.740	0.73	1.860	5.48	1.062
	BR-10	0.575	0.980	1.93	1.768	5.14	1.107
	SWARNA	0.588	0.951	1.73	1.684	4.72	1.074
	IMP. SAMBA MANSURI	0.606	1.020	1.97	2.670	8.89	1.432
	ARIZE 6444	0.581	1.048	2.23	2.061	6.38	1.230
	Mean	0.611	0.977	1.75	1.906	5.58	1.164
	Total Mean	0.600	0.905		1.335		0.946

CD ($P<0.05$) VAR - 0.237, Zn -0.162, VX Zn -0.429

case of no Zn application, content of Zn in post harvest soil was 2.56 mg kg^{-1}. A significant build of Zn in red and lateritic soil may be due to the lower apparent recover (ANR) of Zn by rice crop. pH and EC of soil did not showed much variation due to higher application rate of $ZnSO_4.7H_2O$ in rice bio-fortification programme (Fig. 4).

ACKNOWLEDGEMENT

Authors are grateful to the Indian Council of Agricultural Research, New Delhi for providing necessary financial assistance for research programme.

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