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Response of rice genotypes under different zinc fertilization strategy

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ABSTRACT

Soil zinc (Zn) deficiency limits crop growth and yield besides its low concentration in grain and straw. Growing of Zn efficient cultivars with high crop yield at low Zn supply would represent a sustainable approach to crop production. Therefore, to evaluate Zn efficiency of rice genotypes, twenty eight different rice genotypes were evaluated under various treatments like three levels of Zn viz. low (without Zn), medium (10 kg Zn ha^{-1} soil) and high (20 kg Zn ha^{-1} soil + three foliar sprays of 0.5% Zn). Zinc efficiency index of all genotypes ranged from 65.5 to 102.6 % and Zn uptake efficiency ranged from 53.8 to 107 % with a mean value of 87.1 and 76.5 %. Cultivar GR-101 was having the highest Zn efficiency index as well as Zn efficiency compared to other genotype. Based on grain yield and Zn efficiency, the genotypes Ashoka-20, Narmad, GR-12, GR-3, GR-1 and GR-2 were classified as efficient and responsive, genotypes GR- 11, SLR -51214. GAUR-10 and GR-13 as efficient and non responsive, whereas, genotypes GR-101, GR-104, GR-102 and Lalkad as inefficient and responsive. The Gurjari, AAUDR-1, K-Kamod, GR-9, GR-5, P-2003 SK-20 and GR-7 genotype were classified as inefficient and non responsive. The efficient and responsive genotypes are most desirable as they would produce higher yield under low Zn concentration in soil and responded well under external application of Zn sources.

Key words: *Crop yield, plant nutrient dynamics, rice genotype, zinc efficiency index*

INTRODUCTION

Rice (*Oryza sativa* L.) is one of the major sources of dietary calorie intake across the globe and zinc (Zn) is the essential plant nutrient to produce the good quality crop produce (Mousavi et al., 2013). Deficiency of Zn was first reported in rice crop in soils of northern India (Nene, 1966; Yoshida and Tanaka, 1969). Increasing the production potential of Zn deficiency soil, needs external application of Zn to fullfill the hungry mouth of the growing population. The availability of Zn depends on the size of plant-available Zn pools in soil and other factors like soil pH and types of soil. Deficiency of Zn is now considered most widespread micronutrient disorder in rice particularly in lowland (Neue and Lantin, 1994; Kumar et al., 2017b). The relatively poor productivity of rice in India is also linked with low soil organic carbon content (Kumar et al., 2017a).

The soils of India are sufficient in total micronutrient contents but deficient in their available levels. The contents varied extensively with respect to soil properties, cropping system, climatic factors and management strategies. It is estimated that nearly half of the crop land are deficient in plant available Zn (Singh, 2009; Shukla and Behera, 2011), leading to limit crop yield and nutritional quality of the harvested grains (Shukla et al., 2012; Shukla and Behera, 2012). Lower concentrations of Zn in soil solution mediated the metabolic process in plant and reduce the yield (Welch and Graham, 1999). Intake of Zn deficient food stuff showed lower Zn content in their blood plasma compared to areas which had sufficient available Zn status and lower zinc deficiency in soil (Singh, 2009).

Utilization of large genetic variation for Fe and Zn existing in cereal germplasm is a vital approach to reduce Fe and Zn deficiencies in developing world.

Studies on genotypic differences in ability to increase Zn availability in the rhizosphere for subsequent uptake have focused on the active release of Zn-mobilizing substances from rice roots. Zinc containing phytosiderophores isolated in root exudates of rice crop have ability to enhance the Zn availability in Zn deficient soil (Zhang et al., 1998).

Hence, there is need to improve micronutrient quality, through fortifying the grain/fodder with Zn or increasing the bioavailability through external application of Zn sources. In this paper, effort was made to elaborate response of different rice cultivars with respect to external application of Zn.

MATERIAL AND METHOD

A field experiment was carried out at Main Rice Research Station, Nawagam, AAU, Anand with 28 white and red genotypes of rice selected on the basis of +Zn contents in grain. The initial soil pH, organic carbon and Zn content were 8.65, 0.35 % and 0.34 mg kg^{-1}, respectively. The treatments consisted of three levels of Zn *viz*., control (without Zn), medium (10 kg Zn ha^{-1} soil application through zinc sulphate) and high (20 kg Zn ha^{-1} soil applied through zinc sulphate + three foliar sprays of 0.5% zinc sulphate). At the time of transplanting, recommended levels of nitrogen as urea and phosphorous were applied in addition to Zn treatment.

Rice was harvested at physiological maturity and grain yield was examined at 14% moisture level. For determination of Zn content in grain and straw, samples were dried in an oven at 65 ^{o}C, ground and stored in plastic bag for analysis. Microwave digestion procedure was used to avoid to contamination risk. One gram sample was taken and transferred into digestion vessel, 10 ml of 65 % nitric acid added and was placed into the rotator body of microwave oven and digestion program was recalled. After cooling, digested samples were diluted and filtered in 50 ml volumetric flask and finally make the volume up to 50 ml using ultra pure water for estimation of Zn with the help of Inductively Coupled Plasma-Optical Emission Spectrometer (ICP-OES) manufactured by Perkin Elmer, USA (OPTIMA 7000 DV) and following parameters were calculated (Graham, 1984):

Zinc uptake in grain =Grain yield ×Grain Zn content

Zinc efficiency index = (Grain yield at low Zn)/(Grain yield at high Zn)×100

Zinc efficiency = (Grain Zn uptake at low Zn)/(Grain Zn uptake at high Zn)×100

RESULT AND DISCUSSION

Grain yield

The average grain yield of different genotypes were significantly influenced by zinc application, which varied from mean value of 14.4 to 74.8, 85.2 to186.3 and 109.5 to 216.4 q ha^{-1}, respectively in grain, straw and total yield depending on genotype (Table 1). The grain yield

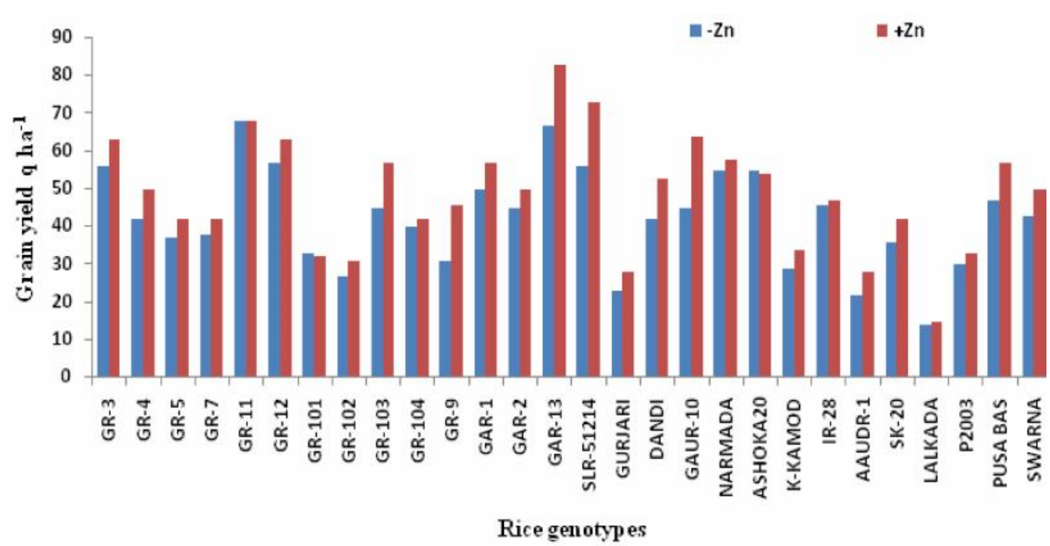

Fig. 1. Effect of Zn application on grain yield of 28 rice genotypes.

Table 1. Average yield and content of Zn in the grain and straw of 28 rice genotypes (data is mean of three levels).

Varieties	Yield (q ha^{-1})			Zn Content (mg kg^{-1})		Zn Uptake (g ha^{-1})	
	Grain	Straw	Total	Grain	Straw	Grain	Straw
GR-3	59.2	127.6	186.8	28.1	23.3	167	338
GR-4	45.5	99.8	145.2	24.1	35.9	110	371
GR-5	38.8	122.5	161.3	29.7	59.2	116	766
GR-7	39.9	103.0	142.9	24.6	39.3	99	368
GR-11	68.8	119.6	188.4	24.6	30.7	169	373
GR-12	61.7	136.6	198.3	22.8	33.8	141	461
GR-101	32.5	124.1	156.6	22.5	34.8	73	434
GR-102	30.0	186.3	216.4	19.2	48.5	58	939
GR-103	52.7	120.0	172.7	19.8	46.9	105	562
GR-104	41.0	162.9	203.9	19.9	33.7	82	512
GR-9	40.8	136.5	177.3	19.1	38.7	78	555
GAR-1	54.8	131.1	185.9	13.3	36.1	73	457
GAR-2	47.4	133.0	180.4	18.3	35.8	87	483
GAR-13	74.8	132.1	206.8	16.1	43.9	121	588
SLR-51214	62.1	129.4	191.5	15.4	39.7	96	497
GURJARI	24.5	114.2	138.7	17.8	38.2	44	448
DANDI	44.2	132.9	177.1	18.2	47.0	82	630
GAUR-10	57.2	120.9	178.1	10.9	33.6	63	394
NARMADA	57.0	142.3	199.3	12.4	40.4	71	583
ASHOKA20	57.6	109.8	167.3	13.2	29.7	76	318
K-KAMOD	31.5	159.4	191.0	11.6	37.6	37	615
IR-28	45.8	92.0	137.8	12.9	27.3	60	247
AAUDR-1	24.3	85.2	109.5	12.9	25.3	32	212
SK-20	40.1	106.0	146.1	12.2	25.1	49	263
LALKADA	14.4	96.6	111.0	11.8	16.3	17	150
P2003	30.9	169.5	200.5	17.3	17.6	54	306
PUSA BAS	53.5	145.4	198.9	14.4	13.3	77	189
SWARNA	45.4	126.9	172.3	16.5	16.4	75	204
S.Em. ±	0.83	3.20	3.48	0.6	2.0	4	22
CD @ 5%	2.35	9.05	9.86	1.7	5.7	10	63
Zn0	42.1	123.2	165.2	16.6	32.5	71	384
Zn1	46.1	127.8	173.9	17.9	33.5	83	449
Zn2	48.6	131.1	179.7	19.1	35.7	93	482
S.Em. ±	0.29	1.15	1.26	0.2	0.6	1	7
CD @ 5%	0.81	3.22	3.54	0.6	1.7	3	20

of genotypes at low Zn ranged from 14.0 to 68.0 q ha^{-1} with an average value of 42.0 q ha^{-1} (Table 2 and Fig. 1). The genotype GR-11 produced highest yield at both the Zn levels and genotype Lalkada produced lowest yield. Similarly, in case of zinc application, increasing levels of zinc significantly increased the grain, straw and total yield of different rice genotypes. The application of Zn fertilizer enhances the uptake in different rice genotypes, which stimulate the metabolic activities, enzymes co-factor process in plant; ultimately enhance the crop yield (Dotaniya and Meena, 2013). This response of rice plants might be due to genotypic variation in some of Zn affected processes as earlier reported by Jiang (2006) for Mn use efficiency in wheat. Similar responses of Zn supply on grain yield of rice were reported by Imran et al. (2015), Nawaz et al. (2015) and Painkra et al. (2015). The improvement in rice grain yield at high Zn application might be due to proper partitioning of nutrients in efficient genotypes and photosynthesis between vegetative and reproductive parts of the genotypes (Joshi et al., 2001). Similarly, PedaBabu et al. (2007) also reported that the yield increase may also be due to enhanced synthesis of carbohydrates and their transport to the site of grain production.

Table 2. Effect of Zn application on grain yield, Zn content, uptake, Zn efficiency and Zn efficiency index of 28 rice genotypes.

Name of cultivars	Grain Yield (q ha^{-1})		Grain Zn Content (mg kg^{-1})		Grain Zn uptake		Zn	Zn
	+Zn	-Zn	-Zn	+Zn	-Zn	+Zn	Efficiency Index	efficiency
GR-3	56.0	63.0	27	30	151	189	88.97	80.1
GR-4	42.0	50.0	23	25	96	125	84.03	77.3
GR-5	37.0	42.0	26	35	95	148	86.15	64.0
GR-7	38.0	42.0	23	28	87	117	90.67	74.5
GR-11	68.0	68.0	21	29	142	198	99.48	72.0
GR-12	57.0	63.0	21	23	120	146	89.83	82.0
GR-101	33.0	32.0	23	22	76	71	102.30	107.0
GR-102	27.0	31.0	18	20	49	62	88.32	79.5
GR-103	45.0	57.0	20	20	90	114	78.92	78.9
GR-104	40.0	42.0	18	20	73	83	96.99	87.3
GR-9	31.0	46.0	18	20	56	92	67.53	60.8
GAR-1	50.0	57.0	13	14	65	80	87.38	81.1
GAR-2	45.0	50.0	17	19	77	95	90.16	80.7
GAR-13	67.0	83.0	16	17	108	141	81.49	76.7
SLR-51214	56.0	73.0	15	17	84	124	76.11	67.2
GURJARI	23.0	28.0	16	21	36	59	80.94	61.7
DANDI	42.0	53.0	15	22	63	116	78.90	53.8
GAUR-10	45.0	64.0	10	11	45	70	70.96	64.5
NARMADA	55.0	58.0	12	13	66	75	94.79	87.5
ASHOKA20	55.0	54.0	13	13	72	70	102.58	102.6
K-KAMOD	29.0	34.0	10	14	29	47	85.41	61.0
IR-28	46.0	47.0	12	15	55	71	96.13	76.9
AAUDR-1	22.0	28.0	12	14	26	39	77.90	66.8
SK-20	36.0	42.0	11	13	40	54	86.45	73.1
LALKADA	14.0	15.0	12	12	17	18	94.22	94.2
P2003	30.0	33.0	15	19	45	62	92.43	73.0
PUSA BAS	47.0	57.0	14	15	66	85	83.07	77.5
SWARNA	43.0	50.0	16	17	68	85	85.50	80.5
Mini	14.0	15.0	10.0	11.0	17	18	67.5	53.8
Max	68.0	83.0	27.0	35.0	151.1	197.8	102.6	107.0
Mean	42.0	49.0	16.7	19.2	71.3	94.2	87.1	76.5

Znic content and uptake in grain and straw

The concentration of Zn in rice grains was significantly influenced by Zn application and genotypes (Painkra et al., 2015). The mean Zn content in grain as well as straw of 28 diverse genotypes varied significantly and across the genotypes (Table 1). The genotype GR-5 recorded highest mean Zn content in grain (29.7 mg kg^{-1}), which is at par with the cultivar GR-3 (28.1 mg kg^{-1}), whereas, Zn concentration in straw was also reported highest in GR-5 (59.2 mg kg^{-1}) among the all genotypes. In case of Zn levels, concentration of zinc in grain ranged from 10 to 27 mg kg^{-1} with mean content of 16.7 mg kg^{-1} at low Zn level, whereas 11.0 to 35.0 mg kg^{-1} with mean content of 19.2 mg kg^{-1} at high level of Zn application. Genotypes GR-3 (27 mg kg^{-1}) and GR-5 (26 mg kg^{-1}) had markedly higher grain Zn content at low as well as 30 and 35 mg kg^{-1} at high Zn level respectively. Increase in Zn concentration in grains may be due to xylem transport of Zn from root and absorption of foliar applied Zn by leaf epidermis, remobilization and translocation into the developing rice grains (Boonchuay et al., 2013). Similar results were also reported by Anandan et al. (2011) that Zn content in traditional genotypes were significantly higher than that of improved cultivars. The average Zn uptake in grain and straw were significantly increased with Zn application. The genotypes also differed in Zn uptake at two levels and across the genotypes. The GR-3 found highest mean Zn uptake in grain at low and high Zn

Table 3. Classification of rice genotypes for Zn efficiency.

Efficient and Responsive (ER)	Efficient and Non Responsive (ENR)	Inefficient and Responsive (IER)	Inefficient and Non Responsive (IRNR)
Ashoka 200F, Narmad, GR-12, GR-3, GR-1 and GR-2	GR- 11, SLR -51214. GAUR-10 and GR-13)	GR-101, GR-104, GR-102 and Lalkad	Gurjari, AAUDR-1, K-Kamod, GR-9, GR-5, Pankhali-203, SK-20 and GR-7

levels. Similar result was also reported by Khan et al. (2012) and Suvarna et al. (2015).

Zinc efficiency

Zinc efficiency is the ability of a plant to grow and produce better crop yield under Zn deficient soils. According to Hafeez et al. (2013), efficient genotypes are those which have high ability to absorb nutrients from soil and fertilizer, produce more grain yield per unit of absorbed nutrient and store relatively little nutrients. In present study, the genotypes Ashoka-20, Narmad, GR-12, GR-3, GR-1 and GR-2 were classified as efficient and responsive, genotypes GR- 11, SLR -51214. GAUR-10 and GR-13 as efficient and non responsive, genotypes GR-101, GR-104, GR-102 and Lalkad as inefficient and responsive and genotypes like Gurjari, AAUDR-1, K-Kamod, GR-9, GR-5, P-2003 SK-20 and GR-7 are classified as inefficient and non responsive on the basis of grain yield and Zn efficiency (Table 3 and Fig. 2). Based on practical value, farmers can be recommended those genotypes which have efficient and responsive are most desirable and produce higher yield under low Zn as well as respond better to Zn additions.

Further to see the effect of maturity duration, all the genotypes were separated in two groups (late genotypes and early genotypes). In light of above criteria the genotypes were classified into four groups' *viz.*, efficient and responsive (Narmada), efficient and non responsive (GR-13 and GR-11), inefficient and responsive (GR-101 and Lalkad) and inefficient and non responsive (K-Kamod and P-2003) for late mature genotypes (Fig. 3). Similarly, in case of early maturing genotypes, it was classified as efficient and responsive (Ashoka-20), efficient and non responsive (Dandi), inefficient and responsive (GR-7) and inefficient and non responsive (GR-9 and Gurjari) on the basis of grain yield and Zn efficiency (Fig.4).

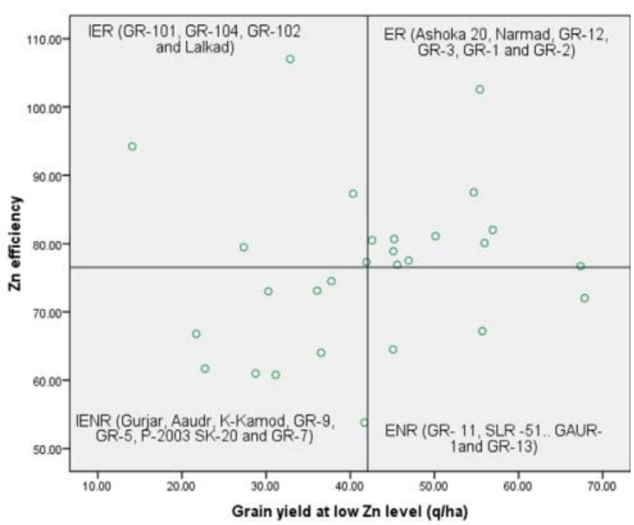

Fig. 2. Classification of rice genotypes for Zn efficiency. ER: Efficient and responsive; IER: Inefficient and responsive; ENR: efficient and nonresponsive; IENR: Inefficient and nonresponsive.

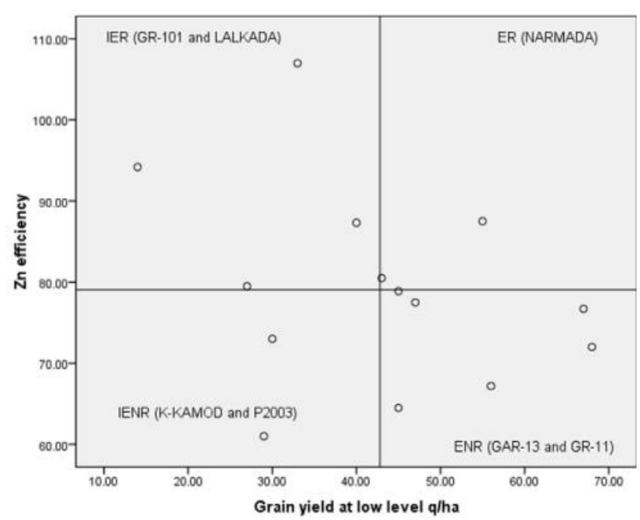

Fig. 3. Classification of late rice genotypes for Zn efficiency. ER: Efficient and responsive; IER: Inefficient and responsive; ENR: Efficient and nonresponsive; IENR: Inefficient and nonresponsive.

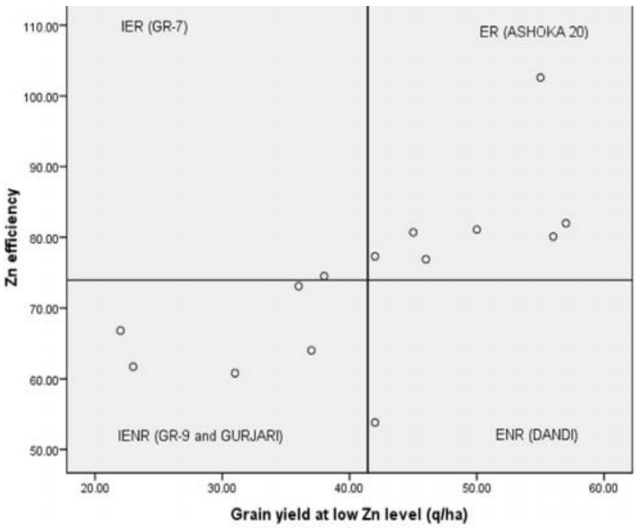

Fig. 4. Classification of early rice genotypes for Zn efficiency. ER: Efficient and responsive; IER: Inefficient and responsive; ENR: Efficient and nonresponsive; IENR: Inefficient and nonresponsive.

CONCLUSION

Zinc nutrition plays an important role in the crop yield performance of a rice cultivar. Soil fertility data showed that rice growing belt of India falls under Zn deficiency and limit the crop yield. In this experiment, different rice genotypes were evaluated against external application of Zn fertilizers through soil and foliar application. Experimental results showed that agronomic bio-fortification through soil and foliar Zn application could be a better approach for enhancement of grain Zn concentration of Zn inefficient genotypes. Thus zinc content in different rice cultivars can be improved through fortifying the grain/fodder with Zn or increasing the bioavailability through external Zn fertilization strategy. The efficient and responsive (Ashoka 200F, Narmad, GR-12, GR-3, GR-1 and GR-2) genotypes are most desirable as they would yield more with higher Zn content under low Zn and also respond better to Zn additions and should be recommended for farmers.

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