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Effect of different levels of zinc on zinc efficiency for maize genotypes under calcareous soil

Vipin Kumar, Rupali, SN Suman, R Laik and Bidisha Borpatragohain

Abstract
Twelve maize genotypes *viz*. Four composites (Laxmi, Swan, Devki and Hemant), four quality protein maize (Shaktiman-1, Shaktiman-2, Shaktiman-3, and Shaktiman-5) and four hybrids (Raja 909, NK 6607, Rasitopless and Rasi 3022) were tested for their response and efficiency to zinc fertilization at Dr. Rajendra Prasad Central Agricultural University Pusa (Samastipur) Bihar. The genotypes were not equally responsive to zinc application. Except composite genotyped all other genotypes (Hybrid and Quality protein maize) showed higher response to zinc application. Among the hybrids the Rasitopless had the highest response followed by Raja 909, NK 6607 and Rasi 3022, the later two having identical responses. Comparing the Quality protein maize their response can be ranked as Shaktiman-5> Shaktiman-1> Shaktiman-3> and Shaktiman-2. The relative grain yield i.e zinc efficiency index varied from 92.5 to 75.5% and relative grain zinc uptake i.e zinc efficiency varied from 77.4 to 44.8% among the genotypes. On the basis of Zinc efficiency, genotypes were classified into efficient and nonresponsive (Raja 909, NK 6607, Rasitopless, Rasi 3022 and Shaktiman-3), efficient and responsive (Shaktiman-1 and Shaktiman-2), inefficient and nonresponsive (Shaktiman-5) and inefficient and responsive (Laxmi, Swan, Devki and Hemant). From a practical point of view genotypes that produce high grain yield at low level of zinc and respond well to zinc additions are the most desirable because they able to express their high yield potential in a wide range of zinc availability.

Keywords: Zinc, maize, genotypes, grain yield, zinc efficiency index, zinc efficiency

Introduction
Maize (*Zea mays* L.) is the third most important cereal crop of world and India ranks after wheat and rice. The maize cultivation in over country is increasing because of high yield potential as well as its high market demand for live stock feed and as a raw material for industry. In India, maize is cultivated in 8.78 m ha with a production of 21.76 MT and the average yield is 2.47 t/ha (PDR 2012-13), which is very low compared to the yield of many maize growing countries of the world. There are several reasons that can explain this yield variation, which cover biotic and abiotic factors. Among the biotic and abiotic factors, unavailability of high yielding varieties and nutrient deficiency (carsky and Reid, 1990: Zuo *et al.*, 1995) [3, 19] are responsible for lower productivity of maize. Zinc deficiency is the most widespread micronutrient deficiency in the world (Fageria *et al.*, 2002) [7]. Zinc deficiency has occurred mainly due to continuous mining of this nutrient from soil and to increase cropping intensity. This element is less available for plant uptake with high pH soils mainly due to their retention by and soul constituents (Hossain, 2007) [13]. Maize is recognized as highly sensitive to Zn deficiency. It is known as an indicator plant for evaluation of Zn deficiency of a soil. So, maize varieties may differ in their sensitivity to Zn deficiency. Zinc deficiency in field crops is emerging as an upcoming nutritional problem world-wide that is adversely affecting crop growth and yield, particularly in calcareous soils with high pH. Amelioration of Zn deficiency with repeated application of fertilizers is a costly affair that demands alternative technology. The selection of crop species that grow and yield well in Zn deficiency soils and also have higher bio-available an in their grain would be a cost effective, environment friendly and sustainable solution to this problem. Screening of genotypes for their adaptability in nutrient deficiency soils is one of the important management practices to escape nutrient deficiency. The different varieties behavior to Zn stress condition as evidenced from the work done under,

micronutrient scheme at Pusa centre with respect to different crops (Sakal *et al.* 1996) [16]. However, the current literature reveals that very few attempts have been made to screen maize varieties to tolerate Zn stress under field condition especially in calcareous soil. Beside this, Zn nutrition studies on yield, concentration, uptake, efficiency and efficiency index for screening of maize varieties are lacking. In view of the importance of maize as a staple food crop, increasing Zn deficiency in soils, upcoming malnutrition problems worldwide and lack of information on screening of efficient maize genotypes form diverse germplasm, a field experiment was conducted to screen maize genotypes for high yield as well as Zn efficiency under Zn deficit conditions.

Materials and Methods

The field experiments were conducted during Rabi season, 2012-13and 2013-14 at the research farm of Dr. Rajendra Prasad Central Agriculture University, Pusa located at latitude 25^0 9" N, longitude 85^0 67" E and 52 m above sea level. The experimental soil was calcareous alluvium having DTPA Zn 0.56 mg/kg, pH 8.56, organic carbon 0.48 % and $CaCO_3$ 34.24 % (Table 1.) The experiment was laid out in a split plot design with three replications, each plot size being 4m x 2.5m. 12 diverse maize (*Zea mays* L.) genotypes, including 4 quality protein maize (QPM), 4 composites and 4 hybrids were evaluated for Zn efficiency. The treatments consisted of three Zn levels *viz*: low (no fertilizer Zn), 5 kg Zn and 10 kg Zn/ha applied as $ZnSO_4$ fertilizer as top dressing With this idea in view, twelve maize genotypes, of which four composites (Laxmi, Swan, Devki and Hemant), four quality protein Maize, (Shaktiman 1, Shaktiman 2, Shaktiman 3 and Shaktiman 5) and four hybrids (Raja 909, NK 6607, Rasi Topless and Rasi 3022), were evaluated on their agronomic response to added Zn. All these genotypes have been procured from TCA, Dholi, I.A.R.I, Pusa and local market. The recommended dose of 120 kg N, 60 kg P_2O_5 and 40 kg K_2O/ha were applied and the other limiting nutrients based on soil test were supplemented to crop. The source of nutrients was urea, single super phosphate (SSP) and muriate of potash (MOP) for N, P, and K, respectively. Intercultural operations *viz*. weeding, irrigation and insecticide spray were done as and when required.

Crop was harvested at maturity and grain yield (q/ha) and grain Zn content were determined. Grains were washed thoroughly with tap water followed by acidified detergent solution rinsed with deionised water followed by distilled water and thereafter dried first in sun and then in hot air oven at 65^0C until constant weight was achieved and then milled. Ground material was digested with 2:1 mixture of nitric (HNO_3) and perchloric acid ($HClO_4$) for chemical analysis. Zinc content in the grain was analyzed by atomic absorption spectra photometry and following parameters were calculated.

Table 1: Physico-chemical characteristics of Zn-deficient soil used for experiment.

Physcio-chemical characteristics	Value
Bulk density (g/cm^3)	1.42
Textural class	Sandy loam
Sand (%)	58.72
Silt (%)	29.05
Clay (%)	12.23
pH (1:2)	8.56
EC (dn/m)	0.36
$CaCO_3$ (%)	34.24
Organic Carbon (%)	0.48
Available N (kg/ha)	224.0
Available P_2O_5 (kg/ha)	18.7
Available K_2O (kg/ha)	106.0
DTPA extractable Zn (mg/ha)	0.56

Zinc uptake in grain = Grain yield x Grain Zn content

Zinc efficiency index and Zn efficiency will be calculated (Graham, 1984).

$$\text{Zinc efficiency index} = \frac{\text{Yield in control plot x 100}}{\text{Yield in treated plot}}$$

$$\text{Zinc efficiency} = \frac{\text{Uptake in control plot x 100}}{\text{Uptake in treated plot}}$$

Results and Discussion

Yield components

The data presented in table 2 showed that there was significant difference in plant height among all maize genotypes. Maximum mean plant height (247 cm) was recorded in NK 6607 followed by Shaktiman 5 (246 cm) while Devki had minimum plant height of 195 cm. All treatment of $ZnSO_4$ had no significant effect on plant height in maize genotypes. In this study, the depicted that $ZnSO_4$ application exhibited no significant difference regarding plant height in maize. However due to genetic variations in maize genotypes showed significant difference regarding plant height. Data pertaining to the cob breadth as affected by different treatments of $ZnSO_4$ application in maize genotypes has been presented in table 2. The results showed that all maize genotypes produced significant difference on cob breadth. Maximum mean cob breadth (4.94 cm) was found in Laxmi, followed by NK 6607 which produced 4.66 cm cob breadth. The application of zinc on cob breadth had been significant and it increased from 4.29 to 4.49 cm. The cob length has been presented in table 2 as influenced by zinc application ranged from 13.38 to 17.06, 14.53 to 18.13 and 15.1 to 19.16 cm at 0, 5 and 10 kg Zn/ha in different varieties. Application of zinc significantly increased average cob length from 15.53 at 0 zinc level to 16.71 and 17.26 cm at 5 and 10 kg Zn/ha.

The 1000-seed weight as influenced by zinc application presented in table 3, ranged from 202to 342, 218 to 359, 225 to 374 g at 0, 5 and 10 kg Zn/ ha, respectively. Application of zinc significantly increased average 1000-seed weight from 296 at 0 zinc level to 316 and 321 g at 5 and 10 kg Zn/ha. Among the maize genotypes, mean1000-seed weight varied from 215 to 356 g. The maximum average 1000-seed weight was recorded in NK 6607 and minimum was found in Hemant. There was a significant difference in zinc concentration due to application of zinc levels and genotypes.

Table 2: Effect of Zn application on plant height and cob breadth on diverse maize genotypes.

Genotypes	Plant height (cm)				Cob breadth (cm)			
	Control	5.0kg Zn/ha	10.0kg Zn/ha	Mean	Control	5.0kg Zn/ha	10.0kg Zn/ha	Mean
Shaktiman 1	226	232	235	231	4.38	4.53	4.58	4.50
Shaktiman 2	196	208	206	203	4.19	4.42	4.46	4.36
Shaktiman 3	217	226	231	225	4.26	4.53	4.6	4.46
Shaktiman 5	239	248	250	246	4.52	4.63	4.69	4.61
Laxmi	212	225	227	221	4.86	4.97	5.00	4.94
Swan	206	213	214	211	4.39	4.52	4.58	4.50
Devki	190	196	199	195	3.72	3.82	3.86	3.80
Hemant	185	198	208	197	3.51	3.62	3.65	3.59
Raja 909	200	211	211	207	4.21	4.46	4.52	4.40
N K 6607	241	248	252	247	4.55	4.7	4.73	4.66
Rasitopless	223	231	232	229	4.36	4.51	4.57	4.48
Rasi 3022	236	248	248	244	4.47	4.62	4.69	4.59
Mean	214	224	226		4.29	4.44	4.49	
	S.Em. (±)		CD at 5%		S.Em. (±)		CD at 5%	
Zn (Z)	3.72		NS		0.06		0.12	
Genotypes (G)	0.55		1.57		0.12		0.35	
Z x G	1.37		4.12		0.30		0.62	

Table 3: Effect of Zn application on cob length (cm) and seed weight on diverse maize genotypes.

Genotypes	Cob length (cm)				1000-seed weight(g)			
	Control	5.0kg Zn/ha	10.0kg Zn/ha	Mean	Control	5.0kg Zn/ha	10.0kg Zn/ha	Mean
Shaktiman 1	16.26	16.78	17.12	16.72	296	325	331	317
Shaktiman 2	15.07	16.18	16.37	15.87	321	332	338	330
Shaktiman 3	15.52	17.05	17.49	16.69	330	338	332	333
Shaktiman 5	16.81	17.72	17.85	17.46	315	340	346	334
Laxmi	15.4	16.63	16.41	16.15	240	255	261	252
Swan	15.23	16.59	17.01	16.28	232	248	253	244
Devki	14.41	15.61	16.83	15.62	329	340	342	337
Hemant	13.38	14.53	15.10	14.34	202	218	225	215
Raja 909	15.15	16.28	16.61	16.01	295	332	336	321
N K 6607	17.06	17.92	18.98	17.99	335	359	374	356
Rasitopless	15.81	17.15	18.21	17.06	315	350	360	342
Rasi 3022	16.23	18.13	19.16	17.84	342	353	359	351
Mean	15.53	16.71	17.26		296	316	321	
	S.Em. (±)		S.Em. (±)		S.Em. (±)		S.Em. (±)	
Zn (Z)	0.053		0.196		0.87		2.59	
Genotypes (G)	0.035		0.099		1.56		4.43	
Z x G	0.051		0172		2.53		7.67	

Grain yield

The grain yield of maize genotypes as influenced by different levels of zinc application has been presented in table 4. The grain yield varies from 54.3 to 69.2, 59.0 to 83.4 and 59.4 to 89.5 q ha^{-1} at 0, 5 and 10 kg Zn/ ha, respectively. Application of zinc significantly increased average grain yield from 62.4 q ha^{-1} at 0 level of zinc to 72.9 and 76.9 q/ ha at 5 kg Zn and at 10 kg Zn/ ha. Among the different groups of maize varieties, different responses were observed in yield of maize to zinc fertilization. Statistically, no variations were observed among hybrids grain. Hybrids, such as Raja 909, NK 6607, Rasitopless and Rasi 3022 produced average yields of 77.8, 80.4, 78.7 and 75.6 q ha^{-1}, respectively. Similarly quality protein maize showed higher response to zinc fertilization as compared to composites. Application of zinc significantly increased grain yield from 71.5 to 75.8 q ha^{-1} in quality protein maize. Quality protein maize, such as Shaktiman 1, Shaktiman 2, Shaktiman 3, and Shaktiman 5 produce average grain yields of 72.9, 75.8, 71.5 and 73.4 q ha^{-1}, respectively. On the other hand, composite genotypes *viz*., Laxmi, Swan, Devki and Hemant produced average yield 63.3, 59.2, 62.8 and 57.6 q ha^{-1}, respectively. The variety NK 6607 produced highest grain yield and lowest was observed with Hemant. The variations might be due to genetical characteristics among the genotypes. From this respect, it can be said that seed yield of maize varied significantly due to zinc fertilization. Similar results were also reported by various scientists (Das *et al.* 1993, Alam and Jahiruddin 2000, Santi *et al.* 1997 and Chowdhury and Islam 1993) [5, 1, 18].

The mean zinc concentration in grain as presented in table 4, ranged from 16.2 to 24.0, 24.6 to 34.6 and 24.4 to 40.4 mg kg^{-1} at 0, 5 and 10 kg Zn/ ha, respectively. The results showed that genotypes Laxmi, Swan, Devki and Hemant accumulated more zinc in grain even under zinc stress condition. It could therefore infer that these genotypes might be having inherent ability to meet their zinc requirement from different forms of native zinc even on low zinc content soil. Application of zinc significantly increased its mean concentration in grain from 19.5 mg kg^{-1} at 0 zinc levels to 30.2 and 33.1 mg kg^{-1} at 5 and 10 Kg Zn/ ha.The maximum average zinc concentration was recorded in NK 6607 and minimum was in Hemant genotype. This might be due to hybrids are fast growing and high yielding and require more nutrients to exploit their full yield potential. Increases in zinc concentration due to zinc application have also been reported by several workers (Harris *et al.* 2007 and Furlani *et al.* 2005) [12, 9].

Zinc uptake by maize grain

The zinc uptake by maize grain in different genotypes as influenced by Zn application has been presented in table 4. The zinc uptake by grain varied from 104.6 to 141.5, 145.6 to 289.6 and 151.0 to 356.8 g ha^{-1} at 0, 5 and 10 Kg Zn/ ha, respectively. Application of zinc significantly increased average zinc uptake by grain from 122.0 g ha^{-1} at 0 level of Zn to 222.8 g ha^{-1} at 5 kg Zn/ ha and 257.3 g/ ha at 10 Kg Zn/ ha. Among the different groups of maize genotypes different responses were observed. Hybrids showed higher response to Zn fertilization as compared to composites and quality protein maize. Similarly, quality protein maize showed higher response to Zn fertilization as compared to composites. Application of zinc significantly increased zinc uptake by grain from 228.1 to 262.6 g/ ha in hybrids. Hybrids such as Raja 909, NK 6607, Rasi topless and Rasi 3022 have zinc uptake of 232.1, 262.6, 228.1 and 237.2 g/ ha, respectively. Similarly, application of zinc significantly increased zinc uptake by grain from 190.9 to 230.1 g/ ha in quality protein maize. Quality protein maize such as Shaktiman 1, Shaktiman 2, Shaktiman 3 and Shaktiman 5 have zinc uptake of 204.6, 227.9, 190.9 and 230.1 g/ ha, respectively. In composite genotypes also, application of zinc significantly increase zinc uptake from 134.5 to 157.9 g/ ha. genotypes *viz*. Laxmi, Swan, Devki and Hemant has zinc uptake of 150.6, 157.9, 151.6 and 134.5 g/ ha, respectively. The genotype NK 6607 has highest zinc uptake by grain and lowest was recorded in Hemant. The different genotypes of the same crop removed differential quantity of applied nutrient (Sakal and Singh, 1995; Latha *et al*., 2001) [17, 14]

The data pertaining to grain yield, Zn content and uptake at low and high Zn supply did not give a clear view of Zn efficiency of the genotypes. The desired genotypes should have higher grain yield and Zn uptake even at low Zn supply and respond better to applied Zn. Keeping this in view Zn efficiency index and Zn efficiency index varied from 75.5 to 92.5 % with 3 genotypes having Zn efficiency index between 75-80 %, 3 genotypes having Zn efficiency index between 80-85 % and 6 genotypes than 85 %. Higher Zn efficiency index means higher yield even at low Zn supply whereas, vice versa for lower Zn efficiency index (Haclsalihoglu *et al*., 1993; Fageria, 2001) [2]. Zn efficiency also varied widely among genotypes ranging from 44.8 to 77.4 %. According to Baliger *et al.* (2001) inter and intra specific variation for plant growth and mineral use efficiency are known to be under genetic and physiological control and are modified by plant interaction with environmental variables. The evaluation of mineral efficiency is useful to screen genotypes for their ability to absorb and utilize nutrients for maximum yields and this efficiency is mainly dependent on uptake efficiency.

To screen Zn efficient genotypes, the genotypes were classified into four groups (Fig. 1.). Fageria and Baliger (1998) [6] suggested this type of classification for the nutrient use efficiency of crop genotypes using nutrient efficiency and average yield of genotypes at low Zn supply. The first group comprised of the efficient and non responsive genotypes that produced more than average yield of 12 genotypes and average Zn efficiency (59 %). Genotypes like Raja 909, NK 6607, Rasi 3022, Rasitopless and Shaktiman 3 fall in this group. The second group of efficient and responsive genotypes produced more than average. Yield of 12 genotypes and response to Zn application was more than average. These genotypes included Shakiman 1 and Shaktiman 2. The third types, known as inefficient and non responsive genotypes, produced was than average grain yield and their response to Zn application was above the average. Genotype shaktiman 5 fall in this group. The genotypes that fall into this group of genotypes produced more than average yield and also more response at applied Zn. These genotypes were classified as inefficient and responsive. The genotypes falls into this group are Laxmi, Swan, Devki and Hemant.

From a practical point to view, the efficient and responsive group of genotypes would be most suitable for cultivation on zinc deficient soils and also respond well to zn application. The second most desirable group is efficient and non responsive that can be planted under low Zn level. The inefficient and responsive varieties can be used in a breeding program for their Zn responsive characteristics. Similar result has also been reported by several scientists in different groups.

Table 4: Effect of Zn application on grain yield (q/ha), grain Zn content (PPM) and grain Zn uptake (g/ha) on diverse maize genotypes.

Genotypes	Grain Yield(q/ha)				Concentration (mg/kg)				Uptake(g/ha)			
	Control	5.0kg Zn/ha	10.0kg Zn/ha	Mean	Control	5.0kg Zn/ha	10.0kg Zn/ha	Mean	Control	5.0kg Zn/ha	10.0kg Zn/ha	Mean
Shaktiman 1	64.7	74.4	79.5	72.9	19.3	30.3	33.6	27.7	124.8	225.3	263.7	204.6
Shaktiman 2	68.5	77.3	81.4	75.8	20.2	32.6	36.4	29.7	138.1	252.2	293.5	227.9
Shaktiman 3	64.3	71.6	78.6	71.5	16.2	30.5	32.5	26.4	104.6	218.9	249.2	190.9
Shaktiman 5	60.3	78.5	81.4	73.4	19.6	34.5	37.6	30.6	118.2	271.3	301.0	230.1
Laxmi	58.5	64.8	66.5	63.3	20.9	26.6	24.4	24.0	118.5	171.1	162.3	150.6
Swan	55.3	60.5	61.7	59.2	24.0	28.5	28.2	26.9	128.2	172.3	173.1	157.9
Devki	56.8	65.2	66.4	62.8	21.5	24.6	26.5	24.2	118.3	159.8	176.8	151.6
Hemant	54.3	59.0	59.4	57.6	20.4	24.6	25.4	23.5	106.9	145.6	151.0	134.5
Raja 909	66.4	80.4	86.6	77.8	17.5	31.9	36.5	28.7	123.6	257.4	315.4	232.1
N K 6607	69.2	83.4	88.5	80.4	19.4	34.6	40.4	31.4	141.5	289.6	356.8	262.6
Rasitopless	67.3	79.4	89.5	78.7	17.1	30.7	35.6	27.8	122.1	243.7	318.5	228.1
Rasi 3022	64.2	79.5	83.2	75.6	17.5	33.4	39.6	30.2	118.9	266.2	326.5	237.2
Mean	62.4	72.9	76.9		19.5	30.2	33.1		122.0	222.8	257.3	
	S.Em. (±)		CD at 5%		S.Em. (±)		CD at 5%		S.Em. (±)		CD at 5%	
Zn (Z)	0.9		3.6		0.032		1.24		3.6		14.0	
Genotypes (G)	1.8		5.2		0.079		2.24		7.6		21.5	
Z x G	3.1		NS		1.37		3.88		13.2		37.2	

Table 5: Zinc efficiency and Zn efficiency index of Maize genotypes.

Genotypes	Zn efficiency	Zn efficiency index
Shaktiman 1	59.4	84.4
Shaktiman 2	58.8	86.7
Shaktiman 3	52.6	86.1
Shaktiman 5	47.6	75.5
Laxmi	73.9	89.3
Swan	77.4	91.3
Devki	74.0	87.0
Hemant	76.0	92.5
Raja 909	48.6	79.8
N K 6607	49.0	80.7
Rasitopless	49.5	80.2
Rasi 3022	44.8	79.3

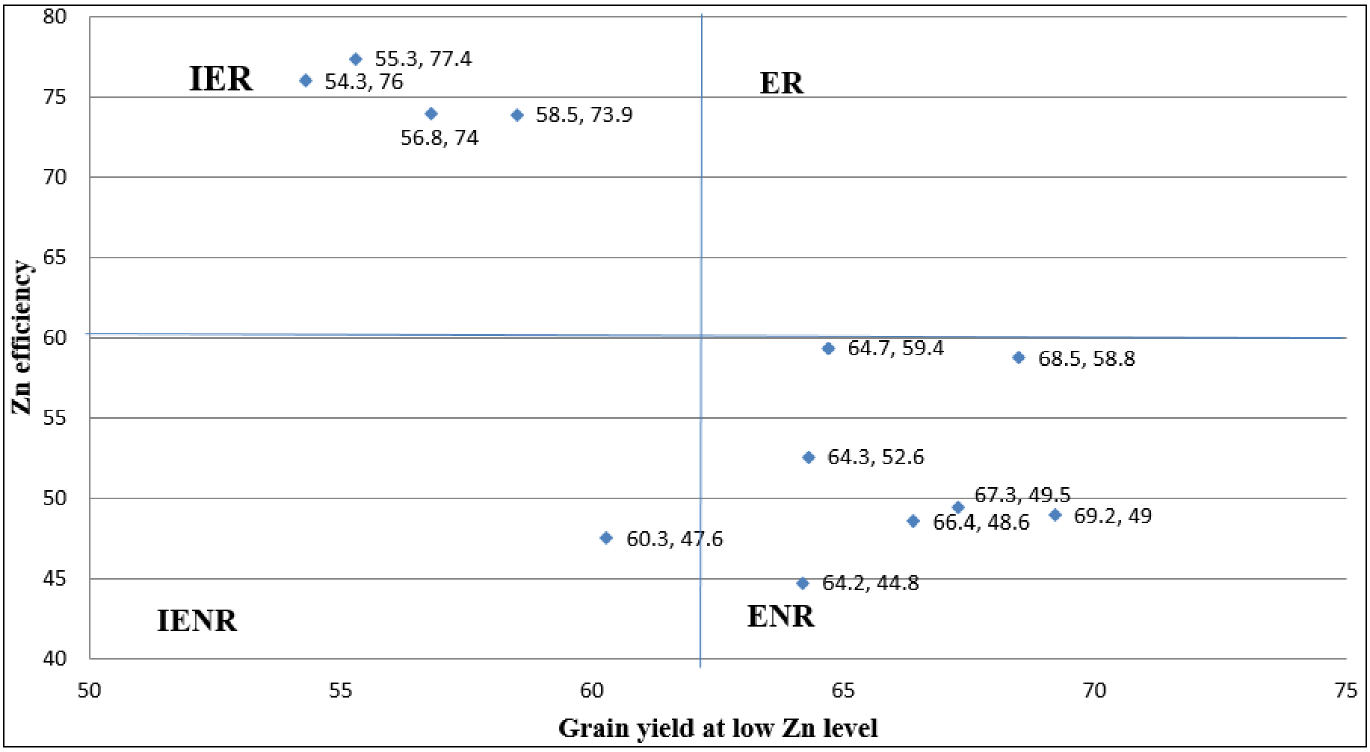

Fig 1: Classification of maize genotypes for Zn efficiency index and Zn efficiency

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