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Screening of rice (*Oryza sativa* L.) genotypes for zinc efficiency under zinc stress condition

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Abstract

Soil zinc deficiency limits the growth and crop yield. Zinc is important micronutrient for both crop growth and human nutrition. In rice production, yields are often reduced and Zn concentration in grains is often low when Zn is in short supply to the crop. This may result in malnutrition of people dependent on a rice based diet. Growing Zn efficient cultivars i.e. cultivars with high yield at low Zn supply would represent a long term solution for sustainable approach to crop production. To evaluate Zn efficiency of 20 diverse rice genotypes, field experiment was conducted during *kharif* seasons for two consecutive year using Zn deficient (0.42 mg kg^{-1}) sandy loam soil, treated with 0 kg Zn ha^{-1} (no Zn low level), 5.0 kg Zn and 10.0 kg ha^{-1}. The relative grain yield i.e. Zn efficiency index from 92.6 to 80.8% and relative grain Zn uptake i.e. Zn efficiency from 71.9 to 49.7% among the genotypes. On the basis of grain yield and Zn efficiency, genotypes were classified on efficient and responsive (Swarna Sub-1, Rajendra Bhagwati, Sudha, RAU 3055 and Janki), efficient and nonresponsive (BPT 5204-Sub-1, RAU 759, Birsamati, Rajshree and Sita), inefficient and responsive (Kalanamak, Kanak, Sugandha and Jeerabati) and inefficient and non responsive Rajendra Subhashni, Ranvir Basmati, Satyam and Radha. From a practical point of view genotypes that produce high grain yield at low level of Zn and respond well to Zn additions are the most desirable because they able to express their high yield potential in a wide range of Zn availability.

Keywords: Zinc, rice, genotypes, grain yield, efficiency

Introduction

The world’s population is estimated to increase from 6 billion to about 10 billion by 2050. To meet the food demand of the growing world population, a large increase in food production is required. It has been estimated that to supply enough food for the world population in 2020, annual cereal production needs to increase by 40%, from 1773 billon tonnes in 1993 to nearly 2500 billion tonnes in 2020 (Frossard *et al.* 2000) [3]. About 85% of the increase in total cereal demand will occur in the developing countries. In rice production, when Zn is in short supply to crop yields are often reduced and Zn concentration in the grains is low. This may result in Zn malnutrition of people who depend on a rice based diet. Micronutrient malnutrition often called “hidden hunger” has been estimated to afflict over tow billion people, especially resource poor woman and children in the developing world and their numbers are increasing (Hambidge, 2000, Von Broun *et al.* 2005) [5, 9]. Crop products constitute the primary source of all micronutrients for humans especially in developing countries. High consumption of cereals based foods with low levels and poor availability of micronutrients is a major factor for the widespread occurrence of malnutrition in human (San, 2006) [8]. However, the Zn concentration in cereals may be increased by applying Zn fertilizer to the soil of directly to the plants (Broadley *et. al.*, 2007) [1]. Zinc deficiency in field crops is emerging as an upcoming nutritional problem worldwide that is adversely affecting the crop growth and yield, particularly in calcareous soil with high pH. Amelioration of Zn deficiency with repeated application of fertilizers is a costly that demands an alternative technology. The selection of crop species that grow and yield well in Zn deficient soils and also have higher bio-availably Zn in their grain would be a cost effective, environment friendly and sustainable solution to this problem.

Materials and Method

The field experiments were conducted during Kharif season for two consecutive year (2010 to 2011) at the research farm, Rajendra Agricultural University, Pusa, Bihar. India. The experimental soil was Zn deficient (DTPA Zn 0.42 mg kg^{-1}) sandy loam soil having pH 8.4, organic carbon 4.8 g kg^{-1} soil, and $CaCO_3$ 32.5%. 20 diverse rice (*Oryza sativa* L) genotypes, including 18 release cultivars and 2 advanced lines with different percentage were evaluated for Zn efficiency. 21 days old seeding was transplanted.

The treatments consisted of three Zn levels viz. low (no fertilizer Zn) and 5.0 kg Zn and 10.0 kg ha^{-1}. A split plot design was used in a factorial arrangement and treatments were replaced three times. The Zn treatments were in the main plots and the genotypes were in the sub plots. At the time of transplanting recommended levels of nitrogen were applied as Urea, phosphorous as single super phosphate and potassium as KCl in addition to Zn treatments. Crop was harvested at maternity and grain yield and grain Zn content were determined. Grains were dried in an oven at 70 °C until constant weight was achieved and then grind. Ground material was digested with diacid 2:1 mixture of nitric acid (HNO_3) and perchloric acid ($HClO_3$) for chemical analysis. Zinc content in the grain was analyzed by atomic absorption spectrophotometer (Lindsay and Norvel, 1978) [7] and following parameter was calculated (Graham, 1984) [4].

Zinc efficiency index = (Grain yield at control Zn/ Grain yield at Zn) x 100

Zinc efficiency = (Grain Zn uptake at control/ Grain Zn uptake at Zn) x 100

Results and Discussion

Grain yield of rice genotypes at low Zn level varied widely from 26.3 q ha^{-1} for genotypes Jeerawati to 42.5 q ha^{-1} for BPT-5204-Sub-1 with an average of 33.7 q ha^{-1} (Table -1). At 10 kg Zn ha^{-1}, grain yield varied from 32.9 q ha^{-1} to 50.6 q ha^{-1} with average values of 40.3 q ha^{-1}. The genotypes RAU 759 produced higher mean grain yield. On an average, Zn application increased grain at high Zn supply might be due to appropriate partitioning of nutrients and photosynthetic between vegetative and reproductive parts in efficient genotypes. The different response of rice plants grown under Zn deficiency might be due to genotypic variation in some of Zn affected processes as reported by Jiang (2008) [6] in aerobic rice. Zinc content in grains of 20 diverse genotypes varied significantly and across the genotypes it increased by 29.8% and 49.4% with application of 5 kg Zn and 10 kg Zn ha^{-1}, respectively. Different genotypes varied widely in their Zn content as well as response to Zn application. The data revealed that application of 5 kg Zn and 10 kg Zn ha^{-1} brought a significant increase in Zn content of rice grains as compared to no application of Zn. Among rice varieties, the highest Zn content in grain was recorded in Sugandha followed by Sita, while the lowest Zn content was noted in Janki followed by Kank. The data revealed that application of 5 kg Zn and 10 kg Zn ha^{-1} significantly increase in Zn uptake by grain as compared to control (no Zn).

The data pertaining to grain yield, Zn content and uptake at control, 5 kg Zn and 10 kg Zn ha^{-1} did not give clear view of Zn efficiency of the genotypes. The desired genotypes should have higher grain yield and Zn uptake to applied Zn, keeping this in view Zn efficiency index and Zn efficiency were calculated (Table 3). Zn efficiency index varied from 80.8 to 92.6% with 3 genotypes having Zn efficiency index >90%. Zn efficiency also varied widely among genotypes ranging from 71.9 to 49.7%. Thus genotypes with high Zn efficiency are desired as they will be efficient scavengers of Zn under low Zn supply.

To screen Zn efficient genotypes, the genotypes were classified into four groups (Fig - 1). Fegeria and Baligar (1993) [2] 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 responsive genotypes that produced more than the average yield of 20 genotypes under Zn deficiency and their Zn efficiency was also higher than average Zn efficiency. Genotypes Swarna Sub-1, Rajendra Bhagwati, Sudha, RAU 3055 and Janki fall in this group. The second group of efficient and non-responsive genotypes produced more than average yield of 20 genotypes at low Zn level, but response to Zn application was lower than the average. These genotypes included BPT 5204-Sub-1, RAU 759, Birsamati, Rajshree and Sita. The third type, known as inefficient and responsive genotypes produced less than average grain yield, but their response to Zn application was above the average. The genotypes that fall into this group were Kalanamak, Kanak, Sugandha and Jeerabati. The fourth group of genotypes produced less than average yield at low Zn level and less than average response to applied Zn. These genotypes were classified as inefficient and nonresponsive. The genotypes that fall into this group are Rajendra Subhashni, Ranvir Basmati, Satyam and Radha.

Table 1: Effect of different levels of zinc application on grain and grain Zn content on diverse rice genotypes

Rice Variety	Grain Yield(q ha^{-1})				Zn concentration in grain(mg kg^{-1})			
	0	5	10	Mean	0	5	10	Mean
Rajshree	35.3	39.0	41.8	38.7	16.5	25.8	32.5	24.9
Kanak	29.6	32.8	34.1	32.2	14.8	17.5	23.6	18.6
Sugandha	32.5	36.6	38.2	35.8	24.8	33.6	35.3	31.2
Ranvir Basmati	27.1	31.2	33.5	30.6	18.8	27.2	30.4	25.5
Birsamati	35.6	37.4	40.3	37.8	17.6	24.7	28.7	23.7
Janki	33.7	38.4	41.6	37.9	14.6	18.5	20.6	17.9
Satyam	31.6	36.5	40.6	36.2	14.2	20.7	23.6	19.5
Swarna Sub-1	40.5	43.8	48.7	44.3	17.5	21.6	25.6	21.6
Radha	30.6	34.5	36.1	33.7	15.2	22.3	30.0	22.5
RAU-3055	35.3	38.3	39.5	37.7	16.6	21.6	27.3	21.8
BPT-5204-Sub-I	42.5	47.9	50.3	46.9	15.8	20.7	24.2	20.2
Rajendra Subhashni	27.6	31.5	33.0	30.7	18.7	25.9	30.6	25.1
RAU-759	40.4	46.6	50.6	45.9	15.7	20.7	25.6	20.7
Sudha	39.4	42.7	44.3	42.1	18.7	21.6	23.5	21.3
Kishori	34.4	39.0	40.3	37.9	14.9	19.3	22.5	18.9
Parbhat	26.6	31.6	34.3	30.8	16.2	18.4	24.4	19.7
Sita	36.7	42.7	45.7	41.7	20.2	26.7	33.7	26.9
Kalanamak	28.6	31.6	32.9	31.0	21.6	26.6	28.4	25.5
Rajendra Bhagwati	39.7	44.6	47.4	43.9	20.7	24.6	26.3	23.9
Jeerawati	26.3	30.6	32.9	29.9	22.7	28.6	31.7	27.7
Mean	33.7	37.9	40.3		17.8	23.3	27.4	
CD (P= 0.05)	Zn – 2.51; Var. – 2.38, Zn x Var. – NS				Zn – 1.11; Var. – 0.85, Zn x Var. – 1.48			

Table 2: Effect of different levels of zinc application on grain Zn uptake on diverse rice genotypes

Rice Variety	Zn uptake in grain (g ha^{-1})			
	T1	T2	T3	Mean
Rajshree	57.8	100.3	136.5	98.2
Kanak	43.6	57.3	80.2	60.4
Sugandha	81.2	123.4	135.6	113.4
Ranvir Basmati	51.1	85.1	102.2	79.5
Birsamati	62.4	95.7	116.3	91.5
Janki	49.1	71.2	85.1	68.5
Satyam	44.5	75.2	96.5	72.1
Swarna Sub-1	71.2	95.1	125.2	97.2
Radha	46.7	77.2	108.6	77.5
RAU-3055	58.2	82.4	108.4	83.0
BPT-5204-Sub-I	66.6	99.5	121.4	95.8
Rajendra Subhashni	51.7	81.9	101.6	78.4
RAU-759	63.6	96.9	129.1	96.5
Sudha	73.5	92.8	104.6	90.3
Kishori	51.6	75.7	91.5	72.9
Parbhat	43.2	58.3	83.8	61.8
Sita	74.3	114.5	154.8	114.5
Kalanamak	61.9	84.2	93.9	80.0
Rajendra Bhagwati	82.4	110.5	125.1	106.0
Jeerawati	59.8	87.8	105.3	84.3
Mean	59.7	88.2	110.3	
CD (P= 0.05)	Zn – 11.8; Var. – 6.59, Zn x Var. – 11.42			

Table 3: Zinc index efficiency and Zn efficiency of rice genotypes

Rice Variety	Zn index efficiency			Zn efficiency		
	T2	T3	Mean	T2	T3	Mean
Rajshree	90.3	85.5	87.9	57.4	43.2	50.3
Kanak	90.9	87.6	89.3	75.7	54.3	65.0
Sugandha	89.0	85.2	87.1	60.2	59.9	60.1
Ranvir Basmati	87.0	81.0	84.0	55.1	50.1	52.6
Birsamati	95.9	89.2	92.6	61.1	54.7	57.9
Janki	88.4	81.9	85.2	62.6	57.7	60.2
Satyam	86.6	78.4	82.5	58.7	47.2	53.0
Swarna Sub-1	92.6	83.2	87.9	67.6	56.9	62.3
Radha	89.6	85.7	87.7	54.9	44.5	49.7
RAU-3055	92.8	90.1	91.5	71.3	54.6	63.0
BPT-5204-Sub-I	89.3	84.4	86.9	61.0	54.9	58.0
Rajendra Subhashni	87.6	83.6	85.6	57.4	51.1	54.3
RAU-759	86.8	80.8	83.8	59.3	49.4	54.4
Sudha	93.0	89.9	91.5	71.9	71.9	71.9
Kishori	88.2	85.3	86.8	62.1	56.6	59.4
Parbhat	84.1	77.5	80.8	67.4	51.4	59.4
Sita	85.9	80.3	83.1	59.4	48.2	53.8
Kalanamak	90.5	86.9	88.7	67.1	66.2	66.7
Rajendra Bhagwati	88.9	83.8	86.4	67.6	66.0	66.8
Jeerawati	86.1	80.2	83.2	62.6	57.2	59.9
Mean	89.2	84.0		63.0	54.8	

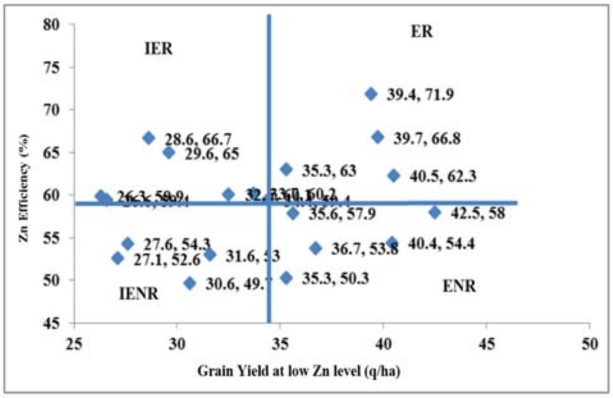

Fig 1: Classifications of rice genotypes for Zn efficiently.

Conclusions

From a practical point of view, the efficient and responsive group of genotypes would be most suitable for cultivation on low Zn soils and respond well to Zn application. The second most desirable group is efficient and nonresponsive that can be planted under low Zn level and procured more than average yield. The inefficient and responsive genotypes can used in a breeding program for their Zn responsive characteristics. The most undesirable genotypes are the inefficient and non responsive.

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