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Resistance to Iron Stress of Some Rice Genotypes in Calcareous Soil under Aerobic Condition

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

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ABSTRACT

A field experiment was conducted in the research farm of Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar during the *Kharif* season of 2013 in iron-deficient highly calcareous sandy loam soil to screen the existing popular rice genotypes for their resistance against iron stress. Lime-induced iron chlorosis in rice is very common in upland calcareous soil. The genotypes responded differently to Fe application with respect to grain and straw yield as well as iron uptake by them. The average grain yield at soil application of 20 kg Fe ha^{-1} and 20 kg Fe ha^{-1} + two foliar sprays at pre-flowering and flowering stages of iron were statistically at par. Hence, 20 kg Fe ha^{-1} soil application may be considered was rated as an optimum level for most of the genotypes. From percent response (figure in parenthesis) of iron application to rice grain yield, the relative susceptibility of genotypes to iron stress may be arranged as Jirabati(37.9) >Prabhat(20.0) >R. Suwasshani(17.9) > Sanwal Basmati(11.5) > Vandana (10.2) > RAUAER-3(6.1) > MTU 7029(4.9) > RAUAER-5(4.4) > RAUAER-4(1.7). The percent response (figure in parenthesis) of iron application to iron uptake by grain, different genotypes may be arranged as R. Suwasshani(91.1) > Jirabati(86.5) >Prabhat(67.3) > RAUAER-3(19.6) > Sanwal Basmati(18.8) > Vandana (17.9) > MTU 7029(12.5)>Swarna Sub-1(11.7)>RAUAER-5(8.9) > RAUAER-4(6.3) . On the basis of iron efficiency (figure in parenthesis) the relative tolerance of rice genotypes to Fe stress may be arranged as RAUAER-4(94.2) > RAUAER-5(91.9) > RAUAER-3(85.6) > Vandana (91.9) > Sanwal Basmati (84.2) >MTU 7029(83.3) > Swarna Sub-1(83.1) >Prabhat(60.6) > Jirabati(55.4) > R. Suwasshani(52.7). The RAUAER-4 was the most efficient genotype followed by RAUAER-5 to tolerate iron stress soil condition.

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Keywords: Rice genotypes; iron stress; susceptible; tolerant; iron efficiency.

1. INTRODUCTION

The world's population is estimated to increase from 6 billion to approximately 10 billion by 2050. To meet the food demand of the growing world population, a large increase in food production is required [1]. 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 billion tonnes in 1993 to nearly 2500 billion tonnes in 2020 (Rosegrant et al. 1999, 2001). About 85% of the increase in total cereal demand will occur in the developing countries. In rice production, when Fe is in short supply to crop yields are often reduced, and Fe concentration in the grains is low. This may result in Fe malnutrition of people who depend on a rice-based diet. Micronutrient malnutrition often called "hidden hunger" has been estimated to afflict over two billion people, especially resource-poor woman and children in the developing world, and their numbers are increasing [2,3]. 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 reduced availability of micronutrients is a major factor for the widespread occurrence of malnutrition in human [4]. However, the Fe concentration in cereals may be increased by applying Fe fertiliser to the soil or directly to the plants [5]. Iron 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. (Yang *et al.,* 2007). Amelioration of Fe deficiency with repeated application of fertilisers is costly that demands an alternative technology. The selection of crop species that grow and yield well in Fe deficient soils and also have higher bio-availably Fe in their grain would be a cost-effective, environment-friendly and sustainable solution to this problem [1].

2. MATERIALS AND METHODS

The field experiments were conducted during *Kharif* season in the year 2013 at the Research Farm, Dr. Rajendra Prasad Central Agricultural University, Pusa, Bihar, India. The experimental soil was Fe deficient (DTPA Fe 5.42 mg kg^{-1}) sandy loam soil having pH 8.4, organic carbon 4.8 g kg^{-1} soil, and $CaCO_3$ 32.5%. 10 diverse rice (*Oryza sativa L.*) genotypes were evaluated for Fe efficiency. 21 days old seeding was transplanted. The treatments consisted of three Fe levels viz. low (no fertiliser Fe) and 20.0 kg Fe and 20.0 kg ha^{-1}+ three foliar sprays at the pre-flowering stage, flowering and milking stage. A split-plot design was used in a factorial arrangement and treatments were replaced three times. The Fe treatments were in the main plots and the genotypes were in the subplots. 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 Fe treatments. The crop was harvested at maternity and grain yield and grain Fe content was determined. Grains were dried in an oven at 70°C until constant weight was achieved and then grind. The ground material was digested with diacid 2:1 mixture of nitric acid (HNO_3) and perchloric acid ($HClO_3$) for chemical analysis. Iron content in the grain was analysed by atomic absorption spectrophotometer (Lindsay and Norve, 1978) and the following parameter was calculated [6].

Iron efficiency index = (Grain yield at control Fe/ Grain yield at Fe) x 100

Iron efficiency = (Grain Fe uptake at control/ Grain Fe uptake at Fe) x 100

3. RESULTS AND DISCUSSION

Grain yield of rice genotypes at low Fe level varied widely from 22.0 q ha^{-1} for genotypes Jeerawati to 43.7 q ha^{-1} for RAUAER-5 with an average of 33.1 q ha^{-1} (Table 1). At 20 kg Fe ha^{-1}+ 3FS, grain yield varied from 31.0 q ha^{-1} to 46.5 q ha^{-1} with average values of 37.2 q ha^{-1}. The genotypes RAUAER-5 produced higher mean grain yield. On an average, Fe application increased grain at high Fe supply might be due to appropriate partitioning of nutrients and photosynthetic between vegetative and reproductive parts in efficient genotypes (Joshi, 2001). The different response of rice plants grown under Fe deficiency might be due to genotypic variation in some of the Fe affected processes as reported by Jiang [7] in aerobic rice. Iron content in grains of 10 diverse genotypes varied significantly, and across the genotypes, it increased by 9.3% and 17.1% with the application of 20 kg Fe and 20 kg Fe ha^{-1}+ 3 FS, respectively. Different genotypes varied widely in their Fe content as well as response to Fe application. The data revealed that application of 20 kg Fe and 20 kg Fe ha^{-1}+ 3 FS brought a

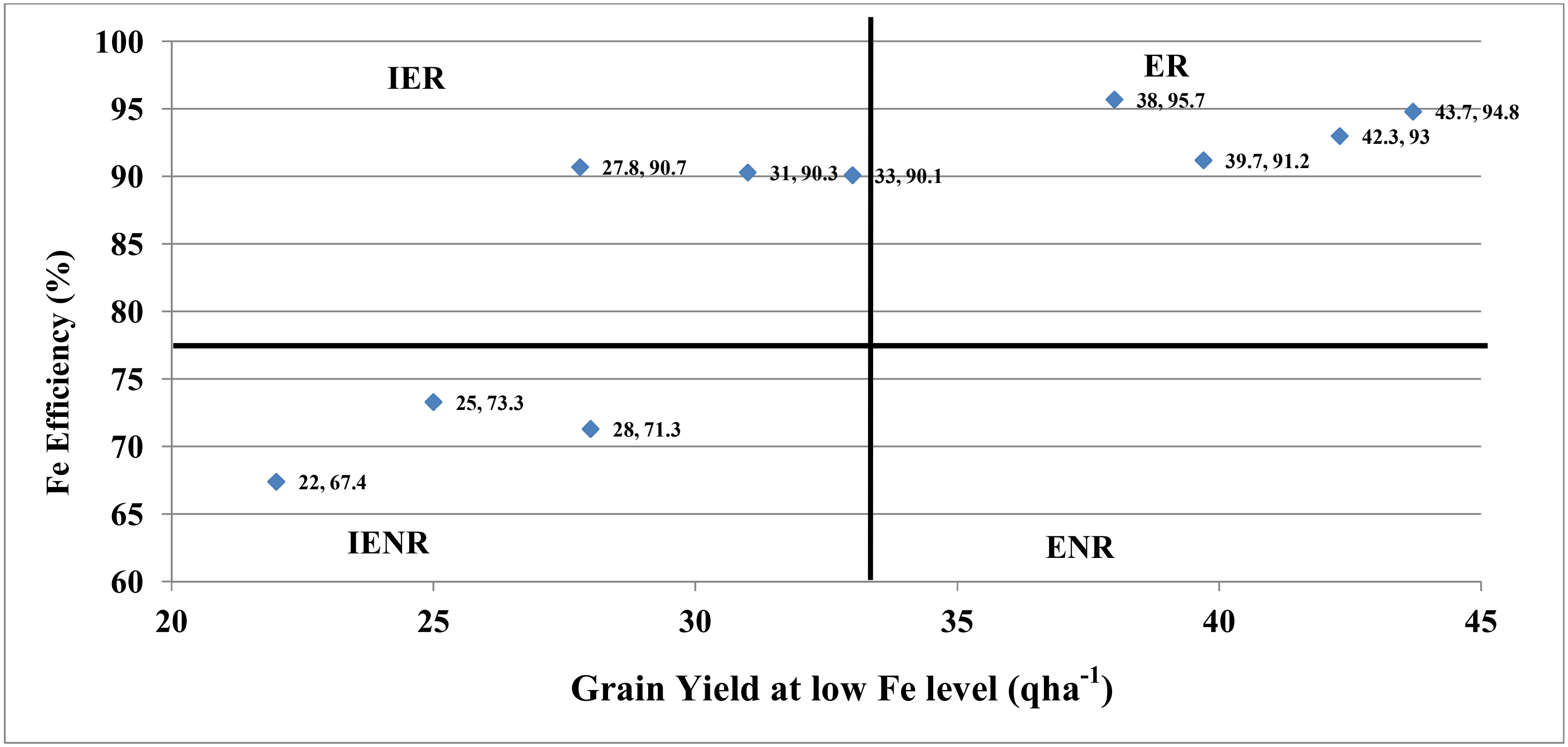

Fig. 1. Classification of rice genotypes for Fe efficiency

Table 1. Effect of different levels of iron application on grain and grain Fe content on diverse rice genotypes

Rice variety	Grain yield (q ha^{-1})				Fe concentration in grain (mg kg^{-1})			
	0	**20 Kg Fe**	**20 Kg Fe + 3 FS**	**Mean**	**0**	**20 Kg Fe**	**20 Kg Fe + 3 FS**	**Mean**
V1 = Swarna sub-1	42.3	43.7	45.7	**43.9**	50.8	53.0	54.4	**52.7**
V2 = Sanwal Basmati	27.8	30.7	31.3	**29.9**	58.3	61.7	63.2	**61.1**
V3 = MTU-7029	39.7	41.3	42.0	**41.0**	46.5	47.0	53.0	**48.8**
V4 = RAU-AER 5	43.7	44.7	46.5	**44.9**	70.9	73.6	73.8	**72.8**
V5 = RAU-AER 4	38.0	38.5	38.8	**38.4**	52.9	54.1	56.3	**54.4**
V6 = RAU-AER 3	33.0	34.7	35.3	**34.3**	42.8	45.0	49.3	**45.7**
V7 =R. Suwashani	28.0	32.0	34.0	**31.3**	30.9	47.4	51.6	**43.3**
V8 = Jirabati	22.0	28.0	32.7	**27.6**	40.2	48.4	59.5	**49.4**
V9 = Prabhat	25.0	29.0	31.0	**28.3**	36.8	46.2	54.8	**45.9**
V10 = Vandana	31.0	33.3	35.0	**33.1**	40.7	42.7	44.5	**42.6**
Mean	**33.1**	**35.6**	**37.2**		**49.2**	**53.8**	**57.6**	
CD (P= 0.05)	Fe – 2.1; Var. – 2.2, Fe x Var. – NS				Fe – 3.5; Var. – 4.3, Fe x Var. – NS			

Table 2. Effect of different levels of iron application on grain Fe uptake on diverse rice genotypes

Rice variety	Fe uptake in grain (g ha^{-1})			
	0	**20 Kg Fe**	**20 Kg Fe + 3 FS**	**Mean**
V1 = Swarna sub-1	214.5	231.2	247.8	**231.2**
V2 = Sanwal Basmati	162.2	187.9	197.5	**182.5**
V3 = MTU-7029	184.7	193.1	222.6	**200.1**
V4 = RAU-AER 5	308.5	328.5	343.5	**326.8**
V5 = RAU-AER 4	200.7	207.4	219.1	**209.1**
V6 = RAU-AER 3	140.8	156.5	173.3	**156.9**
V7 =R. Suwashani	85.7	151.4	176.0	**137.7**
V8 = Jirabati	88.2	134.8	194.3	**139.1**
V9 = Prabhat	91.1	134.6	170.4	**132.1**
V10 = Vandana	126.6	142.8	155.4	**141.6**
Mean	**160.3**	**186.8**	**210.0**	
CD (P= 0.05)	Fe – 15.8; Var. – 17.2, Fe x Var. – 31.5			

Table 3. Iron index efficiency and Iron efficiency of rice genotypes

Rice variety	Fe index efficiency			Fe efficiency		
	20 Kg Fe	**20 Kg Fe + 3 FS**	**Mean**	**20 Kg Fe**	**20 Kg Fe + 3 FS**	**Mean**
V1 = Swarna sub-1	96.8	95.6	**96.2**	92.8	93.3	**93.0**
V2 = Sanwal Basmati	90.6	98.1	**94.3**	86.3	95.1	**90.7**
V3 = MTU-7029	96.1	98.3	**97.2**	95.6	86.7	**91.2**
V4 = RAU-AER 5	97.8	96.1	**96.9**	93.9	95.6	**94.8**
V5 = RAU-AER 4	98.7	99.2	**99.0**	96.8	94.7	**95.7**
V6 = RAU-AER 3	95.1	98.3	**96.7**	90.0	90.3	**90.1**
V7 =R. Suwashani	87.5	94.1	**90.8**	56.6	86.0	**71.3**
V8 = Jirabati	78.6	85.6	**82.1**	65.4	69.4	**67.4**
V9 = Prabhat	86.2	93.5	**89.9**	67.7	79.0	**73.3**
V10 = Vandana	93.1	95.1	**94.1**	88.7	91.9	**90.3**
Mean	**92.0**	**95.4**		**83.4**	**88.2**	

significant increase in Fe content of rice grains as compared to no application of Fe. Among rice varieties, the highest Fe content in grain was recorded in RAUAER-5followed by Sanwal Basmati, while the lowest Fe content was noted in Vandana followed by Rajendra Suwashani. The data revealed that application of 20 kg Fe and 20 kg Fe ha^{-1}+ 3 FS significantly increase in Fe uptake by grain as compared to control (no Fe) [8].

The data pertaining to grain yield, Fe content and uptake at control, 20 kg Fe and 20 kg Fe ha^{-1}+ 3 FS did not give a clear view of Fe efficiency of the genotypes. The desired genotypes should have higher grain yield and Fe uptake to applied Fe, keeping this in view Fe efficiency index and Fe efficiency were calculated (Table 3). Fe efficiency index varied from 82.1 to 99.0% with 8 genotypes having Fe efficiency index >90%. Fe efficiency also varied widely among genotypes ranging from 67.4 to 95.7%. Thus genotypes with high Fe efficiency are desired as they will be efficient scavengers of Fe under low Fe supply [1].

To screen Fe efficient genotypes, the genotypes were classified into four groups (Fig. 1). Fegeria and Baligar [9] suggested this type of classification for the nutrient use efficiency of crop genotypes using nutrient efficiency and an average yield of genotypes at low Fe supply [1]. The first group comprised of the efficient and responsive genotypes that produced more than the average yield of 10 genotypes under Fe deficiency and their Fe efficiency was also higher than average Fe efficiency. Genotypes RAUAER-5, RAUAER-4, Swarna Sub-1 and MTU-7029 fall in this group [10]. The second group of efficient and non-responsive genotypes produced more than the average yield of 10 genotypes at low Fe level, but the response to Fe application was lower than the average. None of the genotypes comes in this group. The third type, known as inefficient and responsive genotypes produced less than average grain yield, but their response to Fe application was above the average. The genotypes that fall into this group were Sanwal Basmati, Vandana and RAUAER-3 [1]. The fourth group of genotypes produced less than average yield at low Fe level and less than average response to applied Fe. These genotypes were classified as inefficient and nonresponsive. The genotypes that fall into this group are Prabhat, Jirabati and Rajendra Suwashni.

4. CONCLUSIONS

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

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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