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"Evaluation of rice genotypes under iron stress condition"

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Abstract

An experiment was conducted in the rainout shelter with five varieties/ genotypes of indica rice, screened under different concentrations of ferric form of iron ($FeCl_3$). Data were recorded on different vegetative traits in which dry root weight and dry shoot weight were found to be more sensitive to excess iron (ferric iron form). On the basis of analysis, we identified 4 genotypes as tolerant (Dagad Deshi, IBD-1, RRF 127, and RRF 105) and Swarna as susceptible genotype for iron toxicity.

Keywords: Rice, iron toxicity, tolerance, iron concentration

Introduction:

Rice is India's preeminent crop and is one of the chief grains and staple food of the people of the eastern and southern parts of the country. India is one of the world's largest producers of rice, accounting for 20% of all world rice production. Rice is the main food for 35 percent of world population as it contains high nutritional values and calorific value. (Bouman *et al.,* 2002). Most of the land approximately 129-million-hectare world land is come under rice cultivation but there is major problem of toxicity and deficiency of nutrient has been reported which accounts for reduction of 100 million hectare from whole world. (Becker and Asch 2005). Iron is an important micronutrient performed many works like chlorophyll synthesis, and it is also important for the structure and function of chloroplast. Iron also show an important role in basic biological processes such as photosynthesis, chlorophyll synthesis, respiration, nitrogen fixation, uptake mechanisms (Kim and Rees, 1992), and DNA synthesis through the action of the ribonucleotide reductase (Reichard, 1993). Absorption of iron take place in two form, first one ferrous (Fe^{+2}) and second one ferric ion ((Fe^{+3}) but the ferrous (Fe^{2+}) ion is majorly absorbed form of iron and it can cause nutrient imbalance or nutrient hampering condition in plants and accounts for Indirect toxicity, this type of iron toxicity is more commonly found in lowland rice. (Fageria *et al.*, 2006 and Fageria *et al.*,1987). Iron toxicity in lowland rice has been reported in South America, Asia, and Africa (Sahu, 1968, Fageria, 1984, Fageria and Rabelo, 1987; Fageria *et al.* 2003 and Sahrawat, 2004). On other hand, in Fe^{3+} form of iron has transported across the plant root membrane by chelating agents (Phytosiderphores) and commonly this absorption occure in upland condition, but this low absorbing ion. So, aerobic rice often suffers from micronutrient deficiency and mainly Fe deficiency, this problem take place due to low release of Fe chelators (phytosiderophores) by rice. (Kreye *et al*. 2009 and Takagi 1976). In aerobic soil where iron is present in ferric form, visual symptoms of insufficient iron nutrition in higher plants easily can be seen in which interveinal chlorosis of young leaves and stunted root growth are common. Thus, plants growing in high-pH soils (low reduction take place) are very poor in developing and stabilizing chlorophyll, as a result yellowing of leaves, poor growth, and reduced yield. Iron toxicity can be considered as a complex nutrient disorder, as its accounts for deficiencies of other nutrients by interfering with other important nutrients (P, K, Ca, Mg, and Zn). Deficiencies of Ca, Mg, and Mn also has been observed in low land. Among the different abiotic stresses, such as drought, cold, heat, salinity, and acidic soils, soil nutrient deficiencies, and toxicities (Kar and Ma, 2018) cause significant grain yield losses, iron toxicity give rise 18 percent loss of the global soil as 18 percent soil are suffered from iron toxicity. (Das *et al*, 2014 *and* Vose,1982) which can change the healthy physiology of soil and also soil process of *eg*. Soil redox potential, soil pH, soil fertility status, and Fe toxicity are responsible for significant grain yield (GY) reductions (Audebert, 1885). In severe iron toxic soil conditions, more than a 50% GY reduction is reported; however, before grain filling iron toxicity can attack in early vegetative stage and can cause complete crop failure (Audebert 1885 and Chérif *et al*, 2009). Iron toxicity is common waterlogged conditions and factors such as reduced cation exchange capacity, poor drainage, high sulfide content, and high organic matter content have led to excessive available forms of Fe in the soil (Becker *et al*, 2005, Nugraha *et al*, 2016). A significant proportion of rice-growing area is affected by Fe toxicity (FT) in China, India, the Philippines, Thailand, Malaysia, and Indonesia, and several countries of West Africa (Gridley *et al*, 2006– Asch *et al*, 2005). So, it become important to understand the genetic of Fe absorption, uptake, and the transporting mechanisms in iron toxic condition, their interactions with other micronutrients. However, not much attention has been given to the development of rice varieties with tolerance to Fe toxicity) (Kar and Panda, 2018, Bashir *et al*,2014 and Dos *et al* 2017), mainly because of this complex trait that is governed by several component traits and is much affected by environmental factors. Here, in this study our main focus is identifying genotypes tolerance to iron toxicity and analyze the effect of iron toxicity on important plant traits.

Material and Method:

Experimental location: The experiment was performed in the rain out shelter of the Department of Plant Molecular Biology and Biotechnology, IGKV, Raipur,

Experimental material: This experiment was conducted by choosing five genotypes namely Dagaddeshi, IBD-1, R-RF-127, R-RF-105 and Swarna. These genotypes were selected on the basis of previous iron toxicity experiment performed in Department of Plant Molecular Biology and Biotechnology, IGKV, Raipur. On the basis of previous performance these genotypes were selected for further experiment.

Experiment method: A hydroponics experiments was conducted for screening of genotypes (Dagaddeshi, IBD-1, R-RF-127, R-RF-105 and Swarna) against iron toxicity. In hydroponics, iron was supplied from the source $FeCl_3$. All genotypes were exposed to different iron doses (0, 40, 80 ppm) of Fe^{+3}.

Hydroponics Experiment -: For conducting hydroponics, healthy seeds of selected five genotypes were germinated in Petri-plates and were subsequently transferred in glass tubes filled with Yoshida nutrient solution, all nutrient were fixed in solution except iron concentration. The iron was given in ferric form by using ferric chloride solution ($FeCl_3$) in three different doses (0, 40, 80 ppm). In all experiments, we took one controlled condition in which iron was present in optimum dose according to the standard dose of Yoshida nutrient solution (Yoshida 1976). The pH of nutrient solutions (4.5) was adjusted on every two days and nutrient solutions were changed every week. Plants were exposed to iron stress condition for 30 days of sowing. After 30 days sowing harvesting and observation recording was done. plant shoot and root were harvested separately and washed with ion free distilled water. Plant materials were dried at about 60^0c and dry matter was determined. Data were taken on different vegetative traits like shoot length, root length, fresh shoot weight, dry shoot weight, fresh root weight and dry root weight. The recorded data were subjected to the factorial CRD analysis.

Result and discussion

Mean comparison table (Table-1) of genotypes exposed to different doses of ferric form of iron revealed that all vegetative traits affected by high dose of iron. Shoot length ranged from 12.9 to 32.07 which was observed respectively for IBD-1 and Swarna at 40 ppm and 80 ppm of iron. Root length was ranged from 7.83 to 20.33 which was observed for dagad deshi at 0 ppm (Controlled condition) and for 40 ppm R-RF-127. Maximum value of fresh shoot weight and fresh root weight was recorded for IBD-1 at 40 ppm and similarly the lowest value was recorded for Swarna at 80 ppm of iron, similarly maximum value of dry shoot weight and dry root weight was found for genotype dagad deshi at 0 ppm (Controlled condition) and for IBD-1 at 40 ppm and minimum value of these trait was observed for Swarna at 80 ppm of iron. Lastly lowest iron content in shoot and root was observed for IBD-1 and R-RF-127 at 0 ppm (Controlled condition) and the maximum value was observed for Swarna. Hence it is clear from result that all vegetative traits were susceptible for iron toxicity, but the dry shoot weight and dry root weight was found as most susceptible trait affected by iron toxicity. (Fig-1 graphs showing values of affected shoot and root weight)

In five selected genotypes Swarna was recorded as most susceptible genotype and IBD-1 was found as tolerant genotype, beside IBD-1, dagad deshi, R-RF-127, R-RF-110 was also recorded as tolerant genotypes.

Iron loading was found maximum at 80 ppm of iron in all genotypes but genotype Swarna was recorded with highest amount of iron revealed that most susceptible nature of Swarna toward iron toxicity. Iron content was found in root more that shoot which represent higher absorption of iron and low translocation, which may be due to low ability of translocation of plant or this hamper ability of plant may be the result of iron toxicity. Iron loading was less in genotypes Dagad deshi, IBD-1, R-RF-110 and R-RF-127 which represent the ability of induction of avoidance mechanisms, allowing the plant to keep lower Fe amounts in its tissues and decreasing Fe translocation to shoots

The most likely cause of iron toxicity due to increased levels of Fe^{+3} in rice genotypes' reliance on a reduction-based approach for iron absorption. It has been reported that there are some Fe (II) transporters (*OsIRT1* and *OsIRT2*), as well as the *OsNRAMP1* gene, were shown to be up-regulated in the roots (30-fold for *OsIRT1* and 64-fold for *OsIRMP1*) in response to ferric iron (Cheng *et al*.,2007). Hence, hydroponics with higher ferric iron without chelating agent may causes iron toxicity due to induction of divalent iron transporters *OsIRT1* and *OsIRT2*.

Another reason for ferric chloride's toxic nature (when there is a higher dose of iron without a chelating agent) is its highly corrosive nature, an aqueous solution of ferric chloride without a chelating agent undergoes hydrolysis and forms hydrates, acid, and precipitates as ferric hydroxide due to the higher amount of ferric chloride. In absence of chelating agents, high ferric iron produces precipitation, which damages root hair and plant cells, resulting in low shoot length, root length shoot weight, and dry weight.

Table: -1 Five genotypes exposed to at 0, 40 and 80 ppm of Fe^{+3}

	Dagaddeshi			IBD-1			R-Rf-127			R-RF-105			Swarna		
Characters	**0 ppm**	**40 ppm**	**80 ppm**	**0 ppm**	**40 ppm**	**80 ppm**	**0 ppm**	**40 ppm**	**80 ppm**	**0 ppm**	**40 ppm**	**80 ppm**	**0 ppm**	**40 ppm**	**80 ppm**
(SL)	22.67	24.33	22.87	25.67	32.07	26.00	26.33	18.90	17.17	26.87	24.67	17.33	19.33	18.97	12.90
(RL)	7.83	14.93	13.27	15.33	18.03	15.47	12.33	20.33	17.07	12.93	18.73	17.27	14.80	12.43	10.00
FSW	0.36	0.44	0.36	0.48	0.73	0.57	0.26	0.44	0.36	0.44	0.44	0.38	0.23	0.53	0.19
FRW	0.52	0.57	0.51	0.60	0.75	0.31	0.47	0.55	0.39	0.35	0.50	0.43	0.63	0.23	0.18
DSW	0.29	0.21	0.17	0.23	0.15	0.13	0.18	0.28	0.17	0.24	0.28	0.26	0.16	0.21	0.16
DRW	0.21	0.31	0.27	0.32	0.42	0.20	0.27	0.25	0.24	0.27	0.34	0.26	0.31	0.17	0.10
Fe^{+3}S	25.00	240.50	343.43	22.63	231.63	352.27	25.27	240.27	292.60	23.97	251.43	351.50	24.93	343.77	457.23
Fe_{+}^{3} R	28.73	248.83	359.87	24.43	248.03	357.63	23.50	248.87	307.50	26.63	255.27	355.77	25.10	354.57	555.77

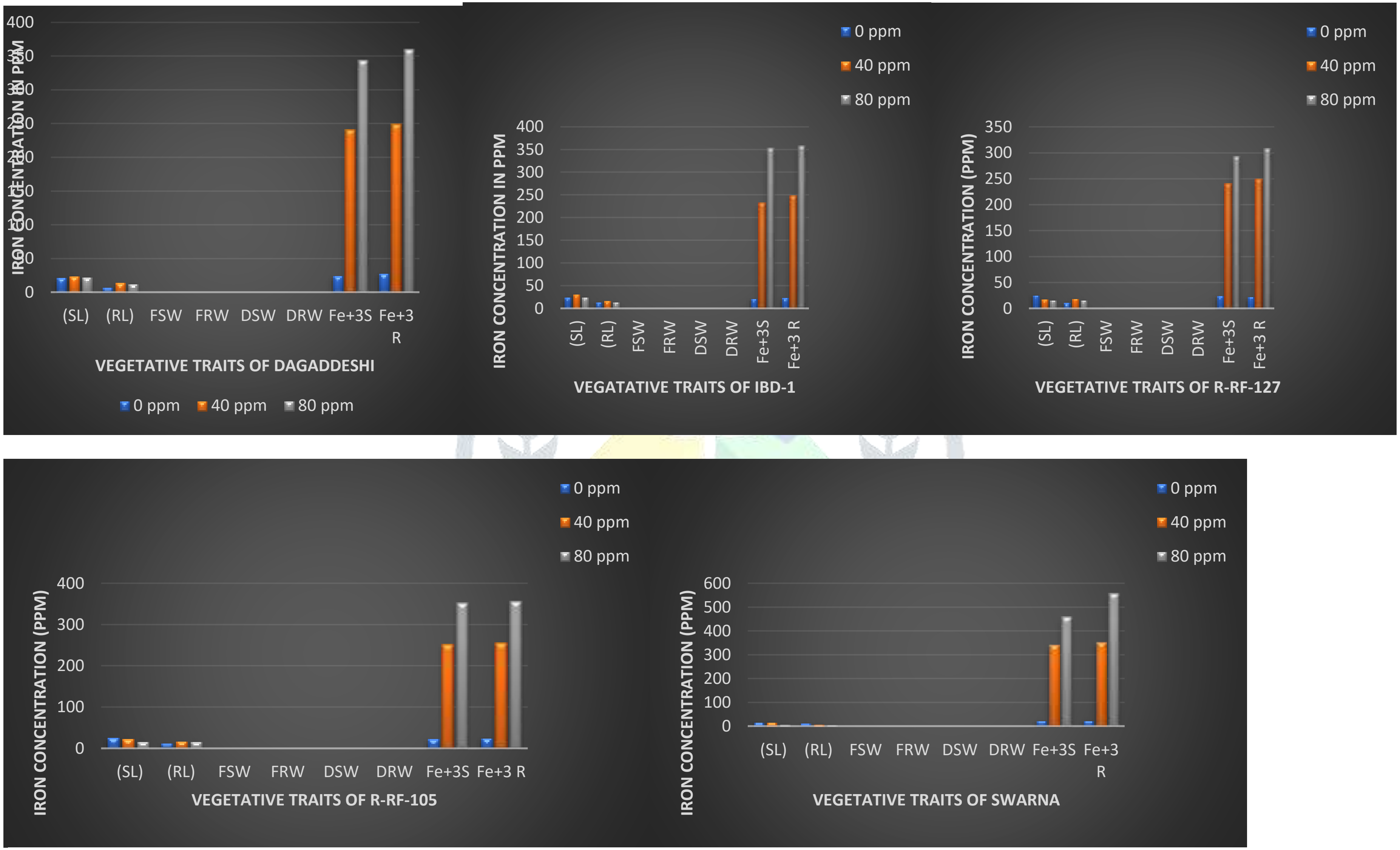

Fig. 1: Graph showing effect of high concentration (0,40 and 80 ppm of ferric chloride) of iron in different traits of five

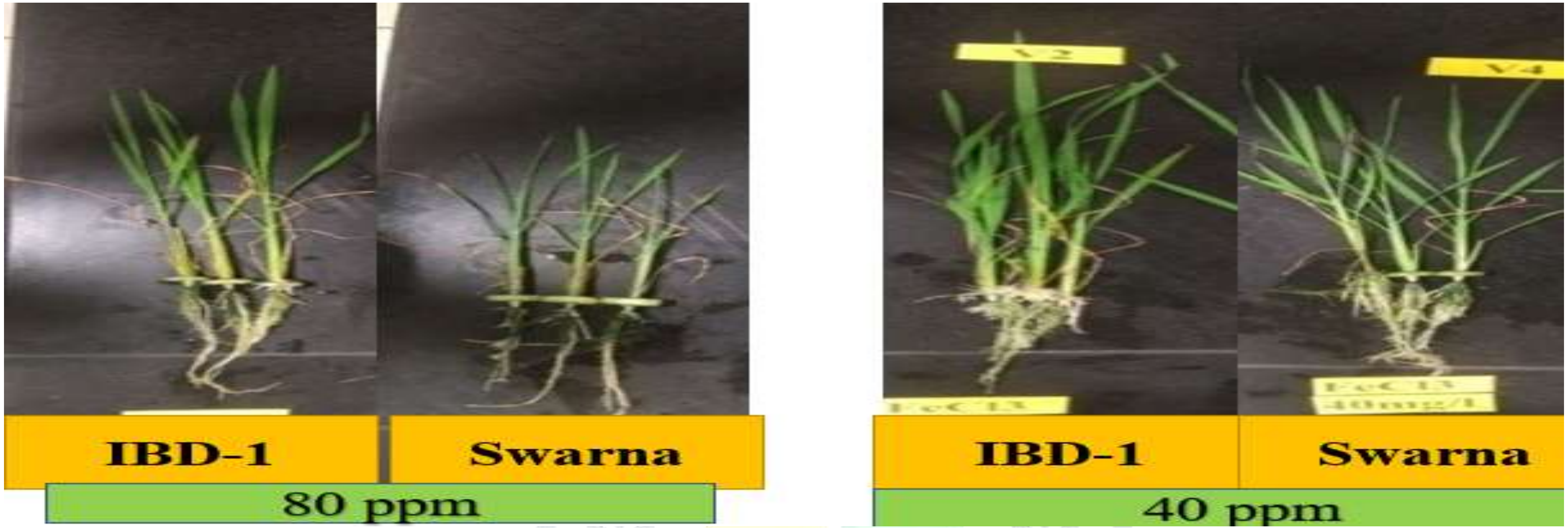

Fig.2- Image of IBD-1 and Swarna exposed to 40 and 80 ppm of Fe^{+3} (ferric chloride)

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