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Correlation studies in morphological and biochemical characters in rice under iron toxic field condition

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Abstract

Eleven rice genotypes selected from laboratory screening experiment was grown under iron toxic field condition. Various characters related to iron toxicity tolerance were studied. Association analysis was carried out among the characters root length, total number of roots(20DAT),number of fresh roots(20 DAT), Visual scoring at flowering (0-9), Visual scoring at maturity (0-9), Iron content in root, iron content in 3rd leaf, iron content in oldest fully opened matured leaf, Iron content in grain, iron content in straw, grain yield per plant. Study showed that visual scoring showed positive correlation with iron content in leaf and negative for grain yield per plant. Root characters exhibited a positive correlation with grain yield. Association analysis revealed that iron toxicity tolerance of genotype is a complex character and selection cannot be done based on a single character. Iron content analysis on various genotypes shows the presence of root based and shoot based tolerance mechanisms.

Keywords: iron toxicity, field experiment, rice, correlation, iron content on various plant parts

Introduction

Rice is one of the most important crops that humans depend for food. Throughout the world rice cultivation is done mainly under low land conditions. In tropical and subtropical regions iron toxicity is an important problem in rice cultivation. The toxicity can cause yield reduction of 12-49%, but this depends on many factors like agroclimatic conditions, tolerance of genotypes and the extent of stress prevailing in the soil (Sahrawat, 2000) [11]. Acidic soils with low pH are usually affected by the stress. Usually under anerobic condition in soil solution the Fe^{3+} will get converted to Fe^{2+} and excess uptake of Fe^{2+} will lead to iron toxicity in plants. The iron toxicity symptoms include bronzing of leaf, Stunted growth and yield reduction. There are differences in responses of varieties under iron toxic condition (Mohanty and Panda, 1991) [7]. Exploring the genetic base of tolerance to iron toxicity can be considered as a cost effective strategy (Shimizu, 2009) [13]. Varietal tolerance to iron toxicity is a complex character, so detailed knowledge about the interdependence of the characters is important in selection and crop improvement programmes. In the present study association analysis was done for the root characters, iron content on various plant parts, grain yield and visual leaf bronzing score.

Materials and Methods

Thirty rice genotypes collected from different research stations under Kerala Agricultural University were screened in laboratory under various iron concentrations (0, 200,400,600 mg l^{-1}) and the best performing genotypes at highest iron concentration 600 mg l^{-1} was selected for field evaluation. The experimental material for the field study includes eleven rice genotypes Asha (MO 5), Pavithra (MO 13), Panchami (MO 14), Uma (MO 16), Pournami (MO 23), Gouri (MO20), Karishma (MO 18), Samyukta (PTB 59), Bharati (PTB 41), Thekkan chitteni (PTB 12).The experiment was conducted in randomized block design with three replications in lowland paddy field. The field was divided in to three blocks and each block were divided in to 11 plots of size $4.5m^2$. The genotypes were considered as treatments and they were randomized to each plot. Germinated seeds were sown in nursery and were transplanted to main field 21 days after sowing. Seedlings were transplanted at a spacing of 20 cm X 15cm between plants. Agronomic practices were carried out according to “Package of Practices Recommendation Crops 2016” of Kerala Agricultural University (KAU, 2016).In the present investigation attempt have been made to study the inter dependence between characters *viz.*, grain yield per plant, root length, root weight, total number of roots, number of fresh roots, dry weight of roots, visual scoring at flowering (0-9), visual scoring at maturity (0-9), Iron content on root, Iron content on 3rd leaf from tip, Iron content in oldest fully opened matured leaf, Iron content in grain, Iron content in straw.

Result and Discussion

Grain yield per plant showed significant positive genotypic correlation with total number of roots (0.467) followed by root length (0.446) whereas negative correlation with visual scoring at maturity (-0.744), visual scoring at flowering (-0.668) and iron content in oldest fully opened matured leaf(-0.568).Visual scoring at flowering showed significant high positive genotypic correlation was recorded between iron content in oldest fully opened matured leaf (0.780) followed by visual scoring at maturity (0.761), iron content in 3rd leaf from tip (0.598) whereas negatively correlated with grain yield per plant (-0.668).Visual scoring at maturity recorded significant positive genotypic correlation with iron content in oldest fully opened matured leaf (0.777), iron content in straw (0.627), iron content in 3rd leaf from tip (0.488) whereas negative correlation was seen with grain yield per plant(-0.744).Iron content on root showed significant negative genotypic correlation with iron content in 3rd leaf from tip (-0.542) and iron content on straw (-0.40).Iron content in 3rd leaf from tip recorded significant positive genotypic correlation with iron content in oldest fully opened matured leaf (0.785).Significant positive genotypic correlation was recorded between iron content in oldest fully opened matured leaf and iron content in straw (0.367) whereas negative correlation with grain yield per plant(-0.568)and iron content in grain (-0.385).

Iron toxicity tolerance in rice is complex. Knowledge about several other characters and their inter dependence is essential for knowing the iron toxicity tolerance of a genotype. Association analysis can easily reveal the interdependence of characters and it will help in determining the direction of selection.

The major symptom for iron toxicity is leaf discoloration (bronzing) and reddish brown spots (Ponnamperuma *et al.*, 1955) [9]. The toxicity symptoms become visible from early vegetative phase in rice. Symptoms first appear as brown spots on leaf surface coupled with reduction in tillering and other yield contributing characters. Iron toxicity symptoms and severity depend on both genotype and soil. Older leaves are mostly affected and the symptom start from tip of leaves and proceed to base was observed between iron content in leaves and visual scoring this was similar to the findings of

Table 1: Genotypic and Phenotypic correlation coefficient (Below diagonal - Genotypic correlation, Above diagonal- Phenotypic correlation)

	RL	**TNR**	**NFR**	**VSF**	**VSM**	**IR**	**ITL**	**IOL**	**IGR**	**IST**	**YD**
RL	1	0.499**	0.353*	-0.252	-0.347*	-0.137	-0.456**	-0.410*	0.308	0.327	0.424*
TNR	0.690**	1	0.193	0.009	-0.024	-0.330*	0.070	-0.127	0.356*	0.430*	0.445**
FR	0.390*	0.303	1	0.114	-0.001	-0.369*	0.230	0.186	0.072	0.213	-0.038
VSF	-0.252	-0.017	0.169	1	0.618**	-0.097	0.514**	0.701**	0.184	0.291	-0.607**
VSM	-0.413*	0.029	-0.057	0.756**	1	-0.068	0.403*	0.717**	0.052	0.564**	-0.696**
IR	-0.256	-0.576**	-0.769**	-0.132	-0.114	1	-0.332*	-0.214	-0.032	-0.259	-0.149
ITL	-0.595**	-0.029	0.302	0.598**	0.488*	-0.542**	1	0.676**	-0.114	0.059	-0.181
IOL	-0.472**	-0.193	0.190	0.780**	0.777**	-0.196	0.785**	1	-0.364*	0.343	-0.530**
IGR	0.323	0.550**	0.102	0.211	-0.056	-0.027	-0.109	-0.385*	1	0.016	0.127
IST	0.363*	0.490**	0.217	0.277	0.627**	-0.40*	0.073	0.367*	0.051	1	-0.175
YD	0.446**	0.467**	-0.031	-0.668**	-0.744**	-0.219	-0.251	-0.568**	0.142	-0.208	1

RL- Root length(cm)
TNR-Total number of roots(20DAT)
NFR-Number of fresh roots (20 DAT)
VSF-Visual scoring at flowering (0-9)
VSM-Visual scoring at maturity (0-9)
IR-Iron content on root($mgkg^{-1}$)
* significant at 5%
** significant at 1%
ITL-Iron content on 3rd leaf from tip($mgkg^{-1}$)
IOL - Iron content in oldest fully opened matured leaf($mgkg^{-1}$)
IGR -Iron content in grain($mgkg^{-1}$)
IST - Iron content in straw($mgkg^{-1}$)
YD - Yield per plant(g)

The iron toxicity symptom usually occurs due to the excess uptake of ferrous iron by root and its deposition on leaves, in the leaves this causes the production free radicals which damage cell components permanently (Thompson and Legge, 1987) [15]. The iron inside the cells produce hydroxy radicals and reactive oxygen species through Fenton reaction. These reactions lead to the appearance bronzing symptom on leaves. In the present study significant positive correlation Asch *et al.* (2005) [1] and Dufey *et al.* (2015) [5]. The leaf bronzing score can be used as a useful criterion for differentiating genotypes for their response to iron toxicity.

Leaf bronzing symptom formed as a result of uptake of excess iron oxidise chlorophyll and causes yield reduction. In the present study grain yield per plant showed a negative genotypic correlation with visual scoring at maturity, visual scoring at flowering. Earlier concurrent result of negative genotypic correlation of grain yield per plant with visual scoring (Audebert and Shrawat, 2000; Audebert and Fofana, 2009) [3, 2] supported the present findings.

Visual scoring at flowering and maturity, correlated positively with each other. Visual scoring at maturity recorded higher value compared to score at flowering this was in accordance with Sikirou *et al.* (2016) [14].

Iron content in 3rd leaf from tip recorded significant positive genotypic correlation with iron content in oldest fully opened matured leaf, this was similar to the findings of Joseph (2015) [6]. Once iron is transported in to the plant system from soil normally gets deposited in various plant parts. Bronzing symptom of iron toxicity first appear on older leaves. In the present study iron content in oldest fully opened matured leaf showed a significant positive genotypic correlation with iron content in straw whereas negative correlation with iron content in grain. One of the iron tolerance mechanism in rice include iron compartmentalization in shoot, the excess iron inside shoot may get deposited in leaves and its transport to grains are reduced.

Studies conducted by Sahrawat, (2004) [12] reported that Effect of iron toxicity in rice is characterized by appearance of leaf bronzing symptom along with formation of red plaques of iron deposition on root and reduction in biomass. Root is the main plant part that has direct contact with iron and many rice genotypes have several tolerance mechanisms associated with root. In most cases tolerance mechanisms associated with roots prevent the uptake and translocation of iron in to upper plant parts. In present study also iron content on root showed significant negative genotypic correlation with iron content in 3rd leaf from tip and iron content on straw similar result was observed by Reddy *et al.* (2019) [10] for iron content in leaf.

When rice plants are grown under excess iron condition iron exclusion operate in some genotypes. The Fe^{2+} present in roots get oxidized to Fe^{3+} by transporting more oxygen to roots from shoots. The Fe^{3+} deposit as iron plaques on root surface and act as a barrier against further iron uptake (Baker and Asch, 2005) [4]. Genotypes showing iron exclusion tolerance mechanism show formation of large amount of iron plaques on root surface. In the present study association analysis revealed that Grain yield per plant showed significant positive genotypic correlation with total number of roots and root length.

Root length was noticed with significant negative correlation with iron content in 3rd leaf from tip, iron content in oldest fully opened matured leaf and visual scoring at maturity. Result was supported by findings of Reddy *et al.* (2019) [10] for iron content in oldest fully opened matured leaf, visual scoring at maturity.

Iron toxicity tolerance in varieties is often associated with root based tolerance mechanisms. There are methods like iron exclusion from roots, iron retention in roots and suppression of iron translocation to shoots, so as under excess iron stress rice varieties use any of these mechanism against ferrous iron present in soil. So genotypes with higher total number of roots and root length under iron toxic condition can provide tolerance to iron toxicity. Total number of roots (20 DAT) exhibited negative correlation was observed with iron content on root. The results were in accordance with Joseph (2015).

Iron toxicity can affect almost all the plant characters. Positive correlation among root weight, root length, shoot length and shoot weight (Wang *et al.* 2013) [16]. In the present study highly significant positive genotypic correlation was recorded between root length, total number of roots (20 DAT), number of fresh roots (20 DAT) the result was in accordance with Reddy *et al.* (2019) [10].

Iron toxicity stress directly affect roots they become dark brown, coarse and short. Studies conducted by Onyango *et al.* (2019) [8] reported that tolerant varieties have the ability to form new fresh roots and that enables them to absorb nutrients continuously for growth. In the present study number of fresh roots and total number of roots (20 DAT) showed significant negative genotypic correlation with iron content on root.

Reddy *et al.* (2019) [10] reported that plants having lower leaf bronzing symptom showed positive correlation between iron adsorbed on root surface and iron content on root. Wu *et al.* (2014) [17] reported that plants having iron excluding mechanism also possess root traits like formation of new roots, aerenchyma which can transport more oxygen to soil. In the present study total number of roots (20 DAT) significant positive genotypic correlation was recorded with grain yield per plant.

Rice plants are grown in nursery, when they are transplanted to main field there are chances of root damage and this can lead to uptake of iron in to plant system. Total number of roots (20 DAT) significant positive genotypic correlation was recorded with iron content in grain followed by iron content in straw.

In the present study iron content analysis in root, leaves, grain and straw revealed that in all genotypes highest iron content was recorded in roots and lowest in grains. High iron content on roots in most of the genotypes may due to its root based tolerance mechanisms and high iron content in shoot with less pronounced bronzing symptom in many genotypes used in study may be due to its shoot based tolerance mechanisms. Clear categorization of the genotypes based on tolerance mechanism requires detailed study.

Conclusion

The association analysis is always important in selection process. In the present study association between root characters, iron content on various plant parts and visual scoring revealed the importance of the characters in a selection process. Visual scoring can be considered as one of the easiest and relevant method in selecting a tolerant genotype due to its high positive correlation with iron content on leaves and negative correlation with yield. Genotypes having well developed root system with many fresh roots under iron toxic condition can be a good indication of their tolerance to the excess iron.

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