Mysore J. Agric. Sci., 50 (2) : 309-311, 2016

Iron Acquisition and Partitioning to Grain in Rice Germplasm Accessions Grown under Aerobic Condition

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ABSTRACT

Iron (Fe) deficiency is a common nutritional problem in cultivation of aerobic rice, consequently resulting in low grain Fe. Characterisation of selected aerobically grown rice accessions showed significant variability in Fe levels in root, shoot, leaves and grain at flag leaf and grain filling (70 and 110 days after planting, respectively) stage. PS- 360 and PS-380 genotypes showed significantly higher level of grain Fe compared to other genotypes. However, there was no strong correlation between shoot and grain iron content and also between Fe remobilization efficiency with grain Fe content. This signifies that, high grain Fe genotypes continues to access iron from roots during grain filling period, besides, remobilization from shoots. The physiological and molecular basis for Fe acquisition and transport was investigated.

RICE is the dominant staple food and energy source of more than half of the world population. Rice consumes 40-46 per cent of the fresh water used in agriculture. Because of diminishing water resources, the productivity of rice has been declining, hence, growing aerobic rice is a unique approach to achieve higher productivity under limiting water conditions.

Aerobic rice often suffers from micronutrient deficiency; especially iron (Fe) deficiency, because Fe^{2+}gets readily oxidized to Fe^{3+}, which will not be accessed by the plants, leading to reduced yield and grain quality (Kreye *et al*., 2009). In addition to an aerobic environment, low release of Fe chelators (phytosiderophores) by rice contributes to the marked susceptibility of rice to Fe chlorosis (Takagi, 1976).

The development of new cultivars with elevated concentrations of Fe would be extremely relevant to alleviate Fe malnutrition. But the lack of knowledge about how nutrients are translocating from vegetative tissues to the seeds is one of the barriers to rice biofortification. Understanding and improving the mechanism of Fe uptake from soil, transport to the shoot and portioning them to the grains has phenomenal relevance. In this regard, the present study is aimed at assessing the genetic variability existing in the rice germplasm for Fe acquisition and transport under aerobic condition.

A set of 200 germplasm accessions of rice were grown aerobically at Zonal Agricultural Research Station, V.C. Farm, Mandya, shoot and grain iron contents were estimated. Twenty genotypes which are contrasting for Fe content (high and low, leaf and grain iron content) were selected along with four regional popular rice varieties (Rasi, BI-33, MAS-946 and KMP-175) and grown aerobically in the *Kharif* 2015 at Department of Crop Physiology, UAS, GKVK, Bengaluru to understand the physiological mechanisms associated with uptake and translocation.

Prior to the start of experiment, the Fe content in the soil was estimated, which was 109.4 ppm. Spatial (root, stem, leaf and grain) and temporal (flag leaf and maturity stage) Fe content were estimated using Inductively Coupled Plasma Optical Emission Spectrometry (ICP-OES) (Thermo Fisher Scientific). The concentrations of Fe were represented in ppm (mg/kg).

Large variability for Fe content in rice genotypes was observed. Analysis of variance showed significant genotypic ($p<0.001$), spatial ($p<0.001$), and temporal ($p<0.001$) difference in the Fe content. A wide range of variations in Fe content observed for root (153.51-286.9 ppm), shoot (116.33-195.12 ppm) and leaf (91.16-132.06 ppm) at flag leaf stage. Even at grain filling stage higher Fe content was seen in root (111.06

to 265.09 ppm) followed by shoot (100.80-140.95 ppm) and leaf (64.87-106.63 ppm). But, a significant ($p<0.01$) reduction in Fe content was noticed in grain across all genotypes (Fig. 1). It clearly indicates the presence of check points for iron partitioning between source (root, stem and leaf) and sink (grain).

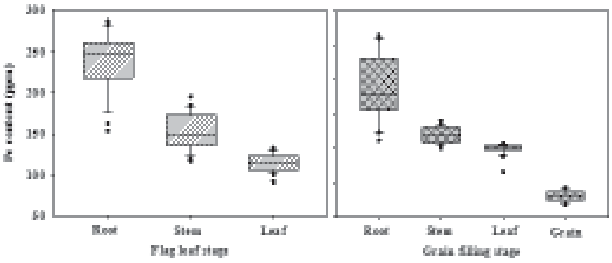

Fig. 1: Spatial and temporal variation in Fe content in rice grown under water limited conditions

Dissimilarity analysis performed using DAR win (Perrier *et al.,* 2003) considering all the measured traits. Genotypes which are behaving similar and dissimilar in acquisition and transport were identified using similarity values (Fig. 2a). Based on the DAR win analysis, high (PS-360, PS-384, PS-369) and low (AC-39019, AC-35170, PS-367) iron uptake and transport genotypes were selected,local checks were in the intermediate group. The genotypes contrasting for Fe content were compared with the local checks (Rasi, BI-33, MAS-946 and KMP-175), since these are aerobically grown varieties (Fig. 2a and b). The genotype PS-360 has higher tissue iron content (root, shoot and leaf) and grain in both flag leaf and grain filling stage.

Genotypes PS-360 (120.4ppm) and PS-384 (120.6ppm) had 6.83 and 6.97 per cent higher leaf

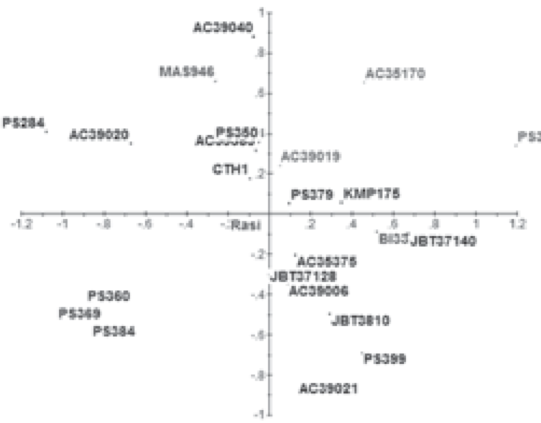

Fig. 2a: Diversity analysis of rice accessions

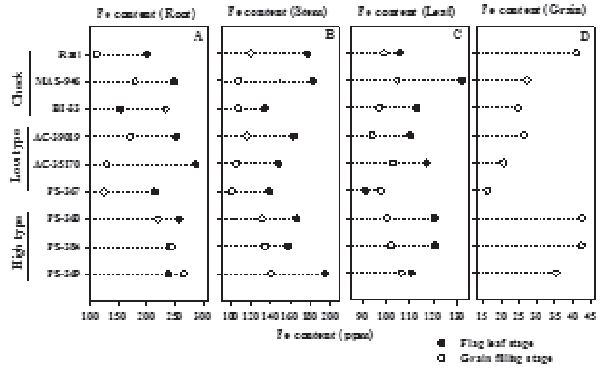

Fig. 2b: Iron content of contrast and checks at flag leaf and grain filling stage

iron content, respectively compared to BI-33 at flag leaf stage. MAS-946 showed more iron content in leaf (132.1 ppm) in the flag leaf stage and (104.6 ppm) in the grain filling stage compared to any other genotypes. But, grain iron content of MAS-946 is less (27.1 ppm). This could be due to less transport of iron from leaves to the grain. Developing grains receive Fe from the roots and from senescent leaves. The level of remobilization from shoot to seed varies by species, rice transports only 4 per cent of shoot Fe to the seeds (Marr *et al.,* 1995), whereas, wheat, transports 77 per cent of shoot Fe to the seeds (Garnett and Graham *et al.,* 2005).

PS-369 having the less leaf iron content in the flag leaf stage (110.7 ppm) and relatively high Fe content in the grain filling stage (106.6 ppm) compared to the low types and checks BI-33 and MAS-946. But, the grain iron content is more, this may be because of direct acquisition and transport of iron from root to the grain. This is evidenced by the fact that,under the condition of Fe deficiency seed Fe can be remobilized from shoot and from continued root uptake (Raul *et al.,* 2013). And variety Rasi being low in iron content in the leaf at both flag leaf and grain filling stage has virtually more grain Fe content as of high types (PS-367 and PS-384). On the contrary, AC-35170 having more iron content in leaves (99.3 ppm), failed to transport into the grain (20.6 ppm). Consequently, there was no correlation between shoot and grain iron content (Fig. 3a). This shows less transport from leaves to grain eventhough high iron content in the shoot and leaf in some genotypes. Hence, Fe uptake and remobilisation at later stages may be relevant (Joe *et al.,*2009).

Therefore, Fe partition efficiency of contrasting genotypes and checks was calculated based on ratio of grain iron content to the shoot Fe content (Fig. 3b). Besides, the Fe remobilization efficiency was also calculated based on change in shoot Fe content between flag leaf and grain filling stage.

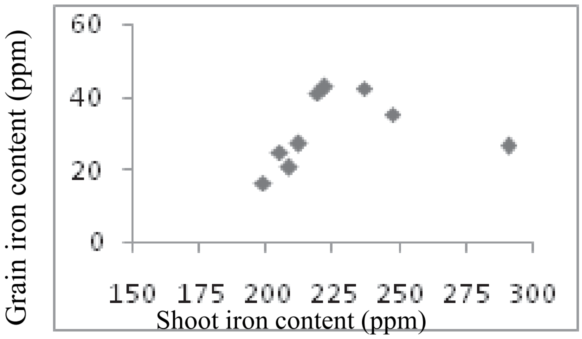

Fig. 3(a): Correlation between shoot iron content and grain iron content

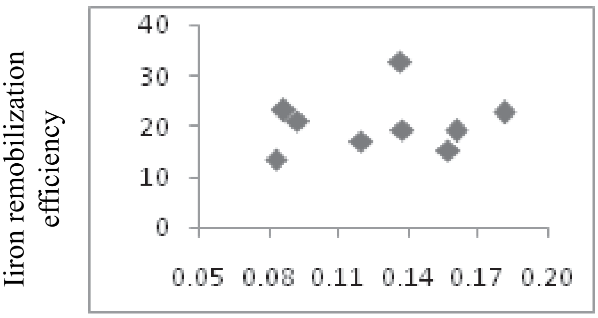

Fig. 3(b): Iron partition efficiency of contrast and checks

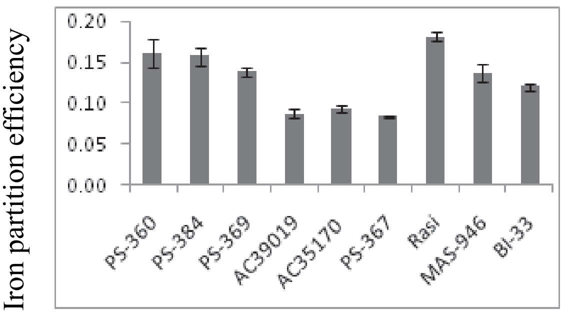

Fig. 3(c): correlation between Fe partition efficiency and remobilization of Fe from flag leaf to grain filling stage

Fe partition efficiency ranged from 0.083 to 0.181. High uptake and transport types showed high Fe partition efficiency. Rasi showed high Fe transport efficiency followed by high types (PS-360 and PS-384). There is no correlation observed with Fe partition efficiency and remobilisation efficiency (Fig. 3c). Hence, it can be inferred that, grain Fe content is determined both by remobilisation and also direct uptake and transport to grains during grain development stages. So, identification of high iron acquisition and remobilisation efficiency types to pack more Fe into developing endosperm helps in high grain iron content.

Exploring rice germplasm that are adapted to upland conditions may have potential traits or allele for enhancing Fe acquisition and transport from root to grain and also superior remobilization from shoot. Such rice genotypes with high uptake and remobilisation efficiency can be utilized for the bio-fortification and for trait development. A comprehensive physiological and molecular analysis is underway to understand physio-molecular regulation of Fe acquisition and transport in rice contrasts differing in these characteristics.

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(Received : May, 2016 **Accepted :** June, 2016**)**