Assessing yield losses due to iron toxicity in lowland rice under the field conditions

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Abstract

In Sri Lanka, iron toxicity is recognized as one of the most widespread soil constraints for rice production, particularly in the low country wet zone. This paper investigates plant growth and yield production resulting from iron toxicity in five rice varieties and two advanced breeding lines cultivated on naturally iron-rich soils at the Regional Rice Research and Development Centre, Bombuwala. The experiment was conducted in the 2017/2018 *maha* season. The randomized complete block design with three replicates was used combing the seven treatments which included three rice varieties and two advanced breeding lines of unknown iron tolerance, and a further two varieties with known tolerant and susceptible traits. The susceptibility/tolerance to iron toxicity was assessed using five endpoints indicating growth and yield production. Significant differences between the seven exposed rice types were noted for all the recorded traits, with some showing superior performances for selected traits. Taking each measured endpoint individually, the lowest leaf bronzing score was recorded in Bw14-820, lowest number of days to 50 % heading in Bw272-6b, highest number of tillers in Bw14-820 and maximum grain yield in Bg366. The tallest plants were recorded in Bw267-3, although for paddy, a 'moderate height' is more desirable. Considering a combination of the desirable traits i.e. with regard to all five recorded endpoints, the advanced breeding line Bw14-820 and the variety Bg366 could be taken as showing the highest tolerance to iron toxicity, suggesting that they could be recommended to overcome iron toxicity conditions in lowland areas in the wet zone of Sri Lanka. These varieties could also be further used to develop more tolerant strains of rice in future breeding programmes in the country.

Key words: Advanced breeding lines, iron toxicity, paddy yields, rice varieties

Background

Rice (*Oryza sativa* L.), has been a major cereal crop for the past 5000 years, and is currently the staple diet of 3 billion people around the world. Rice occupies approximately 33 % of the total cultivated land extent in Sri Lanka, accounting for 0.8 million ha (CBSL, 2010) and is grown under more diverse environmental conditions than any other food crop in Sri Lanka (Panabokke and Punyawardena, 2000). In the wet zone, about 80 % of the rice cultivations are within the Low Country Wet Zone (LCWZ) (Wickramasinghe *et al*., 2016). However, rice cultivation in this region is hampered by soil factors such as high iron content and salinity and poor drainage conditions, and the frequent occurrence of flash floods.

Iron toxicity is recognized as one of the most widespread soil nutritional disorders in the lowlands of Sri Lanka and is considered a major constraint to rice production in this region (Bentota *et al*., 2013). Soil solutions may contain varied levels of iron (from 10 to 2000 mg L^{-1}) in the form of Fe^{2+} (Becker and Asch, 2005). A typical symptom of iron toxicity is the copper coloring of leaves – commonly known as "bronzing", which is an indicator of iron toxicity (Bode *et al*., 1995). This may be accompanied by growth retardation and yield losses, although sometimes, such negative impacts may occur in the absence of leaf bronzing (Onaga *et al*., 2013). Reported yield losses due to iron toxicity may range from 10 to 90 % which depends on the inherent tolerances of the paddy varieties (Cherif *et al*., 2009). Thus, one of the practical ways in which to overcome the detrimental impacts of iron toxicity is to cultivate rice varieties that show a high degree of tolerance. In the present investigation we screen five rice types of unknown iron tolerance, which include existing rice varieties and new breeding lines, for iron toxicity tolerance. Two varieties of known iron tolerance are used as references. Tolerance is assessed in terms of five endpoints which are related to growth and yield production in paddy.

Objectives

The overall objective of this study was to screen rice varieties and advanced breeding lines for iron toxicity tolerance under natural iron-rich soil conditions. In doing so we compare the different test varieties and lines in terms of the five selected endpoints of toxicity based on which we could identify rice varieties or lines that are better suited for cultivation in iron-rich soils. Additionally, the findings may shed light on varieties or lines which could be used as parental stocks in future rice breeding programmes in Sri Lanka.

Materials and Methods

Seeds from five rice varieties Bg300, Bg366, Bg359, Bw267-3 (tolerant check), Bw272-6b (susceptible check) and the two advanced breeding lines Bw14-820, Bw13-3-1184 were used for the study. Pure seeds of the above varieties were obtained from the Regional Rice Research and

Development Centre (RRRDC), Bombuwala, Sri Lanka. The soils at the site are known to be rich in iron and are thus capable of inducing toxic symptoms in rice (Gunarathne *et al*., 2016). The seeds were soaked in water overnight, incubated and pre-germinated for 60 h on petri-dishes lined with filter papers inside a growth chamber following Becker and Asch (2005). Six-day old seedlings were transplanted in 1 m x 1.2 m plots, one seedling per hill, at a spacing of 20 cm x 20 cm (following recommendation of Department of Agriculture (DOA), Sri Lanka). A Complete Randomized Block Design, with three replicates was used. This consisted of seven plots per replicate, combining the seven treatments. Land preparation and all cultural practices were done according to the DOA recommendations.

The intensity of leaf bronzing, number of days to 50 % heading, plant height, number of tillers and grain yield were used as endpoints of toxicity. To assess leaf bronzing, a standard evaluation system developed by the International Rice Research Institute (IRRI, 2014) with leaf bronzing scores (LBS) ranging from 0 to 9 was used. The numbers of days to 50 % heading, plant height (cm), tillers per plant and yield kg/plot were also determined through field observations.

Results

The results revealed that the seven rice varieties/lines differed significantly in terms of the five measured end points used to assess iron toxicity tolerance (Table 1). Considering the LBS, Bw14-820 and Bw267-3 showed the lowest score of 1 indicating high tolerance, followed by Bw13-3-1184, Bg300 and Bg366. In sharp contrast, the highest LBS (9) was recorded in Bg359, where all the plants died thus showing a high degree of susceptibility. With respect to the number of days to 50 % heading, the longest duration was recorded in Bg300 (115 days) followed by Bw13-3-1184 (93). Interestingly these two are 3-month varieties, the symptoms indicating delays in flowering and maturity by up to 20 - 30 days, confirming their susceptibility (Becker and Asch, 2005). With regard to plant height, Bw267-3 showed the maximum growth (92.37cm) while the most stunted were Bw14-820 and Bw272-6b. It must be noted that tall paddy plants are prone to lodging and therefore moderately sized plants (semi-dwarf) are preferable (Belaya, 1979). Considering the numbers of tillers, Bw14-820 ranked on top with 9 tillers while the two varieties Bw272-6b and Bw267-3 had the lowest number of tillers. Higher numbers of tillers are the desirable trait because it is associated with higher grain yields (Chakravarty and Barthakur, 1980). In terms of grain yield, the highest was recorded from Bg366 with 1.28 kg/plot whilst the lowest was in Bw272-6b. It has been shown that the selection for a combination of two or more characters against abiotic stresses is more effective than selection for a single character (Chang and Wu, 1976). Taking into consideration the desirability of the traits, an overall assessment is shown in Table 2.

Table 1: Performance of the test rice varieties in terms of the five assessed end points of toxicity

Varieties/ Advanced Breeding Line	Leaf Bronzing Score	Days to 50% heading	Plant Height (cm)	Number of Tillers	Grain Yield kg/plot
Bg300	3.00±0.00	115.47±2.78	82.97±8.75	8.67±4.80	1.15±0.08
Bg359	9 .00±0.00	-	-	-	-
Bg366	3.13±0.50	81.00±2.19	77.87±6.59	6.27+1.53	1.28±0.14
Bw13-3-1184	2.00±0.00	93.53±1.61	80.70±7.69	7.77±4.28	0.59±0.02
Bw14-820	1.03±0.18	84.40±1.67	68.77±5.02	9.70±2.27	0.61±0.02
Bw267-3	1.27±0.45	83.77±1.25	92.37±9.95	6.23±2.06	0.23±0.06
Bw272-6b	6.67±0.75	78.57±1.27	73.37±6.07	3.90±1.02	0.20±0.01

- No values are given due to 100% mortality in plants

Table 2: The overall ranking of the varieties in terms of the five assessed characters (IRRI, 2014)

Variety	Leaf Bronzing Score	Days to 50% heading	Plant Height	Number of Tillers	Grain Yield kg/plot
Bg300	Moderately tolerant	Delayed flowering	Semi-dwarf	Moderate	High yield
Bg359	Highly Susceptible	-	-	-	-
Bg366	Moderately Tolerant	Normal	Semidwarf	Medium	High yield
Bw13-3-1184	Tolerant	Delayed flowering	Semidwarf	Medium	High yield
Bw14-820	Highly Tolerant	Normal	Semi-dwarf	Medium	High yield
Bw267-3	Highly Tolerant	Normal	Tall	Low	Low yield
Bw272-6b	Susceptible	Normal	Semidwarf	Low	Low yield

Accordingly, the present study has shown that when considering all of the five traits, the advanced breeding line Bw14-820 and the variety Bg366 maintains desirable traits under iron rich conditions and hence displays the highest tolerance levels. Based on these findings, the advanced breeding line Bw14-820 and the variety Bg366 could be recommended to overcome iron toxicity conditions in lowland areas in the wet zone of Sri Lanka. This paddy variety / line could also be further used in future breeding programmes to develop more tolerant rice strains to overcome iron toxicity.

Conclusion

The present study which screened five rice types of unknown iron tolerance, based on a combination of five end points of toxicity associated with growth and yield production in paddy plants, has shown that the two – the variety Bg366 and the advanced breeding line Bw14-820 are sufficiently tolerant to iron toxicity, and could hence be recommended for cultivation in iron-rich lowland wet zone soils, in Sri Lanka.

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