LEAF BRONZING SYMPTOM SCORE AS RELATED TO GRAIN YIELD OF RICE UNDER IRON TOXICITY OF ACID-SULFATE SOIL AREA

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ABSTRACT

Excessive Fe^{2+} uptake of rice plant can cause iron toxicity in most of acid wet land environment. Deleterious effect of iron may interfere metabolic processes and cause damage to rice plants, which is marked by red-brownish leaf discoloration or leaf bronzing symptoms (LBS). In some extent of level scoring of LBS may relevant to reducing of grain yield and can be use as criterion selection. Since, high yielding is main goal of rice breeding for acid-sulfate soil environment, it is therefore important to understand the correlation between yield and leaf bronzing symptoms. Here, we study the yield performance of 22 breeding lines under iron toxicity and determine correlation between yield and leaf bronzing symptom of iron toxicity. A randomized complete block design with three-four replications was used in the two acid-sulfate soil area, Karang Agung (South Sumatera) and Belandean (South Kalimantan) in the dry season 2016. Response of rice genotypes to iron toxicity was observed on leaf bronzing symptom, yield, and yield components. The research resulted there were 6 lines have consistency high grain yield and LBS score in two locations, that were (1) B13586E-KA-9-B; (3) B13988E-KA-20, (8) B13983E-KA-13-3, (10) B13983E-KA-13-1, (14) B13925E-KA-46, (17) B13926E-KA-1 with LBS score 3 - 5. Two lines have high yield, but are not consistent with LBS score, that were (21) B14039E-KA-1 and (22) B14009E-KA-39. Leaf bronzing symptoms has significant and negative correlation with grain yield (r=-0.537). Leaf bronzing symptoms is effective as one of criterion selection to get high yielding under iron toxicity in hotspot area.

Keywords: criterion selection, iron toxicity, leaf bronzing symptom

INTRODUCTION

Iron is a micro nutrient needed by plants on very small quantities. Concentration of iron in plant tissue is normal on range of 100-200 ppm. If concentration of iron in soil more than 300 ppm, this condition is toxic for rice plant (Tanaka & Yoshida, 1972).

Iron toxicity in rice can be observed on bronzing and dark symptoms, plant root systems is not developed, inhibited flowering, asymilat synthesis process is stopped, plant is dwarf, roots is thick, brown, rough, and retracted, stems and leaves is decay (Yamauchi & Peng, 1995; Dobermann & Fairhurst, 2000). Bronzing symptoms are fully visible on the leaves that play role as a source of photosynthesis, beginning with the presence of a small brown stain spread from leaf tip to the base of the leaf. More symptoms are leaves become yellowing and dry up, followed by a very high rate of respiration which in turn all leaves become yellowish and brown (rust), or the leaves will be purple, stiff, and hard. This condition indicates a very severe level of iron toxicity (Yamanouchi & Yoshida, 1981).

Iron toxicity in rice plants can decrease grain yield. Grain yields decreased by 52% (Ismunadji *et al.,* 1973), 70% in susceptible varieties and 30% in tolerant varieties (Virmani 1977), even 90% in severe-level of iron in the fields (Suhartini, 1992). Growth abnormalities due to iron stress decrease rice yields by 15 - 30%, even harvest failures in severe iron poisoning (Audebert & Sahrawat, 2000). Hotspot for Fe toxicity is an area with a relatively high Fe levels, which can seriously affect rice production. Fe levels vary from 10 to 2000 ppm (Diatta *et al.*, 1998).

In plant genetic improvement, selection strategy is a key to progress. While breeding for complex traits such as abiotic stress tolerance, two types of selection are distinguished: direct selection based on yield and indirect selection using secondary traits such as leaf rolling, leaf bronzing score, plant height, root and shoot biomass, tissue Fe concentration, chlorophyll content or agronomic traits other than yield. Rice breeding programs aiming at improving the tolerance to Fe toxicity have mainly used yield for direct selection and leaf bronzing score as a secondary trait under Fe toxicity (Abifarin, 1989; Gridley *et al.*, 2006).

Audebert and Fofana (2009) reported that for every increase in LBS by one grain, the yield is reduced by 500 kg ha^{-1}. There are a few other reports of a negative correlation between bronzing score and yield under Fe toxicity stress (Sahrawat *et al.*, 1996; Nozoe *et al.*, 2008; Onaga *et al.*, 2013). The relation between LBS and grain yield could depend on the type and number of entries used, and experimental conditions.

The key secondary trait should have sufficient genetic variability, it should be easier and less expensive to measure than grain yield itself, it should have high heritability, and it should have positive genetic correlation with yield (Laffite *et al.*, 2003). The leaf bronzing symptom (LBS) is a key secondary trait. Leaf symptoms are commonly rated visually using LBS (IRRI, 2002). The score is graded on a scale of 0 – 9 where 0 means normal growth and 9 indicates that almost all plants are dead or dying. As it is only a visual score it can be measured rapidly and it is also relatively easy to measure. However, several contradictory reports exist regarding the relationship between yield and LBS. It is possible to develop good varieties combining high yield with low LBS (Gridley *et al.,* 2006).

Here, we study the yield performance of 22 breeding lines under iron toxicity and determine correlation between yield and leaf bronzing symptom of iron toxicity.

MATERIALS AND METHODS

Experiment was conduct in acid-sulfate area, which were Karang Agung, Banyuasin, South Sumatera and Belandean, Barito Kuala, South Kalimantan on dry season of 2016. The materials used were 22 breeding lines for swampy area and 4 check varieties.

Experimental design used in each location was Randomized Complete Block Design with four replication in Karang Agung, and three replication in Belandean. Response of plant to iron toxicity was observed on leaf bronzing symptom (LBS) score (Shimizu *et al.,* 2005), plant height, time 50% flowering, yield, and yield components.

Data were analysis using analysis of variance, combine analysis of variance, and correlation analysis. Person correlation was calculated to identify correlation between quantitative traits. Spearman's rank correlation was calculated to determine the relationship between yield, yield component, plant height, time of 50% flowering and LBS. All analysis was perform using STAR software.

RESULTS AND DISCUSSION

Performance of Genotypes

Grain yield of genotype tested in Karang Agung were range from 3.11 to 4.18 ton ha^{-1}. INPARA varieties were not significantly different with susceptible variety IR 42. Average of INPARA 9 grain yield was relatively higher so it was used as check in this analysis.

Table 1. Grain yield and leaf bronzing score of breeding line in acid-sulfate area

No	Genotype	Grain yield (ton ha^{-1})			LBS	
		KA	BLD	Mean	KA	BLD
1	B13586E-KA-9-B	4.18	3.50	3.95	3	4
2	B14299E-KA-46	3.13	2.84	2.96	3	3
3	B13988E-KA-20	3.81	3.15	3.59	3	4
4	B14308E-KA-34	3.45	3.48	3.40	3	4
5	B14360E-KA-17	3.35	2.78	3.10	7	5
6	B13983E-KA-6-3	3.58	3.07	3.39	3	5
7	B13971E-KA-23-1	3.60	3.16	3.35	3	5
8	B13983E-KA-12-3	4.06	3.39	3.75	3	4
9	B13984E-KA-8-2	3.24	2.44	2.86	3	4
10	B13983E-KA-13-1	3.60	3.46	3.55	3	5
11	B13983E-KA-7-3	3.67	2.87	3.25	5	5
12	B13970E-KA-23-3	3.65	3.11	3.38	3	4
13	B13925E-KA-7	3.07	2.86	2.97	3	5
14	B13925E-KA-46	4.14	3.25	3.71	3	5
15	B13926E-KA-23	4.12	2.96	3.55	3	5
16	B13925E-KA-42	3.26	2.63	2.94	3	4
17	B13926E-KA-1	4.14	3.15	3.65	3	5
18	B14010E-KA-20	3.72	3.18	3.51	3	5
19	B14039E-KA-15	3.11	2.94	3.01	3	5
20	B13996E-KA-1	3.19	2.35	2.81	3	5
21	B14039E-KA-1	3.66	3.15	3.51	1	3
22	B14009E-KA-39	3.55	3.77	3.75	1	4
23	IR42	3.45	3.25	3.31	1	2
24	INPARA 3	3.88	3.47	3.63	1	3
25	INPARA 8	3.96	2.76	3.36	1	5
26	INPARA 9	3.60	4.28	4.09	1	3
	LSD (5%)	0.51	0.75	-		
	CV (%)	10.0	14.6	12.1		

LBS = leaf bronzing score, KA = Karang agung, grain yield was calculated from four replication, BLD = Belandean, grain yield was calculated from three replications; Mean = overall mean, was calculated from three replication of each location.

Four genotype have grain yield higher than INPARA 9 in Karang Agung, that were (15) B13926E-KA-23, (14) B13925E-KA-46, (17) B13926E-KA-1, and (1)

B13586E-KA-9-B. Other genotypes were not significantly different with INPARA 9. Leaf bronzing symptom (LBS) score ranged from 1 to 7. LBS score of four genotypes with higher grain yield was 3. B14039E-KA-1 (21) and B14009E-KA-39 (22) have low LBS, even the grain yield were not significantly different with INPARA 9 (Table 1). Six genotype could be considered to evaluate in next trials.

Grain yield in Belandean was ranged from 2.76 to 4.28 t/ha. INPARA 8 has low grain yield (2.76 ton ha^{-1}). INPARA 9 has highest grain yield (4.28 ton ha^{-1}). Only B14009E-KA-39 (22) that has an equivalent yield with INPARA 9. Other genotypes have lower yield than INPARA 9. Leaf Bronzing Symptom (LBS) score of Belandean showed higher than Karang Agung, ranged from 2 to 5. B14009E-KA -39 (22) was 4 and INPARA 9 was 3.

Table 2. Plant height, number of productive tillers, and time of 50% flowering of breeding line in acid-sulfate soil area

No	Genotype	Plant height (cm)			No. of tillers			50 % Flowering (HSS)		
		KA	BLD	Mean	KA	BLD	Mean	KA	BLD	Mean
1	B13586E-KA-9-B	103	107	105	11	20	15	92	89	91
2	B14299E-KA-46	95	105	102	14	18	16	91	79	85
3	B13988E-KA-20	94	104	100	23	17	22	96	90	92
4	B14308E-KA-34	101	117	108	11	18	15	91	77	83
5	B14360E-KA-17	93	108	101	12	18	16	92	79	86
6	B13983E-KA-6-3	101	108	106	14	18	16	93	82	86
7	B13971E-KA-23-1	105	124	116	13	16	15	93	81	88
8	B13983E-KA-12-3	104	110	109	14	16	14	92	80	85
9	B13984E-KA-8-2	108	121	116	13	18	16	94	80	87
10	B13983E-KA-13-1	103	116	111	13	18	16	93	86	89
11	B13983E-KA-7-3	102	109	106	13	17	15	96	86	90
12	B13970E-KA-23-3	113	127	121	16	18	17	92	80	85
13	B13925E-KA-7	92	107	101	15	15	16	92	77	84
14	B13925E-KA-46	99	122	112	14	16	16	92	80	85
15	B13926E-KA-23	103	109	107	13	17	15	92	81	86
16	B13925E-KA-42	94	105	101	15	17	17	93	78	85
17	B13926E-KA-1	94	107	99	14	17	15	91	77	85
18	B14010E-KA-20	110	111	111	13	16	15	89	82	85
19	B14039E-KA-15	96	113	104	9	18	13	96	81	89
20	B13996E-KA-1	107	116	113	13	16	15	91	76	83
21	B14039E-KA-1	96	110	105	12	19	15	95	86	90
22	B14009E-KA-39	99	105	102	15	18	17	89	86	88
23	IR42	89	103	96	19	19	21	105	90	98
24	INPARA 3	93	109	103	13	16	15	92	83	87
25	INPARA 8	106	108	108	16	16	16	92	87	89
26	INPARA 9	105	109	108	10	17	14	93	79	85
	LSD (5%)	8.9	5.1	8.3	7	2.2	-	5	4.3	4.8
	CV (%)	6.3	2.8	4.8	35	7.6	24.9	3.7	3.2	3.4

KA = Karang agung, was calculated from four replication, BLD = Belandean, was calculated from three replications; Mean = overall mean, was calculated from three replication of each location.

Combined analysis of variance showed genotype and genotype × environmental interaction was not significantly different. The interaction was not significant may because the narrowness of the genetic diversity of the tested lines (sister line). Field evaluation of large population in Fe-toxic soil conditions with high precision and repeatability would be the ideal situation since varieties would be tested in the target environment or in very similar conditions. However high variability in the distribution of Fe, even in the same field, resulting in large experimental errors and large G × E interaction on grain yield greatly impairs varietal selectin and breeding efficiency for tolerance to Fe toxicity (Sikirou *et al.,* 2015; Cherif *et al.,* 2009; Drame *et al.*, 2010).

Average of grain yield was ranged from 2.81 - 4.09 ton ha^{-1}. INPARA 9 has high yield (4.09 ton ha^{-1}). Based on consistency of grain yield and LBS score in two locations, there were 6 lines have consistency high grain yield and LBS score in two locations. The six lines were (1) B13586E-KA-9-B; (3) B13988E-KA-20, (8) B13983E-KA-13-3, (10) B13983E-KA-13-1, (14) B13925E-KA-46, (17) B13926E-KA-1 with LBS score 3 - 5. Two lines have high yield, but are not consistent with LBS score, that were (21) B14039E-KA-1 and (22) B14009E-KA-39.

Plant height in Karang Agung was ranged from 89 to 113 cm (Table 2), was lower than Belandean which ranging from 104 to 124 cm (Table 2). Mean of plant height was ranged from 99 to 121 cm, the range is ideal for swampy rice.

Table 3. Number of filled and unfilled grains tillers, and weight of 1000 grains of breeding line in acid-sulfate soil area

No	Genotype	No. of filled grains			No. of unfilled grains			W1000 (g)		
		KA	BLD	Mean	KA	BLD	Mean	KA	BLD	Mean
1	B13586E-KA-9-B	133	111	126	27	27	29	23.6	21.9	22.7
2	B14299E-KA-46	111	116	120	22	29	26	24.3	23.1	23.6
3	B13988E-KA-20	128	149	139	18	27	22	23.2	22.6	22.9
4	B14308E-KA-34	126	113	121	12	24	18	26.0	26.1	26.1
5	B14360E-KA-17	145	137	140	18	27	21	23.1	22.3	23.0
6	B13983E-KA-6-3	130	122	127	13	24	17	24.5	21.3	22.8
7	B13971E-KA-23-1	152	133	144	27	30	30	23.5	23.1	23.1
8	B13983E-KA-12-3	140	155	150	23	29	27	23.5	22.3	22.9
9	B13984E-KA-8-2	106	123	114	39	40	42	25.4	23.8	24.5
10	B13983E-KA-13-1	145	137	145	25	63	44	23.2	21.0	22.1
11	B13983E-KA-7-3	138	122	128	20	31	26	23.2	21.8	22.5
12	B13970E-KA-23-3	155	164	160	17	31	26	25.3	23.8	24.6
13	B13925E-KA-7	109	139	126	12	14	14	23.9	21.7	22.9
14	B13925E-KA-46	156	152	160	22	23	23	23.3	21.3	22.2
15	B13926E-KA-23	166	159	165	26	39	33	22.6	20.2	21.4
16	B13925E-KA-42	119	149	139	8	22	15	24.0	19.9	21.9
17	B13926E-KA-1	147	131	139	12	29	21	21.4	18.4	19.9
18	B14010E-KA-20	199	156	175	17	42	29	23.4	21.8	22.6
19	B14039E-KA-15	153	137	144	37	53	45	24.7	23.8	24.3
20	B13996E-KA-1	123	107	120	18	28	22	25.5	23.1	24.4
21	B14039E-KA-1	143	131	144	29	45	38	24.5	23.5	24.2
22	B14009E-KA-39	156	137	149	15	19	17	23.5	21.2	22.2
23	IR42	115	114	121	24	23	21	19.6	18.5	19.0
24	INPARA 3	147	150	151	29	33	32	24.9	23.6	24.3
25	INPARA 8	137	122	136	15	40	25	25.4	23.6	24.7
26	INPARA 9	131	154	150	20	29	25	23.5	23.3	23.6
	LSD (5%)	29	36	-	11	18.7	-	1.2	1.3	1.3
	CV (%)	15.0	16.2	15.2	36.3	36.1	36.8	3.5	3.6	3.5

KA = Karang agung, was calculated from four replication, BLD = Belandean, was calculated from three replications; Mean = overall mean, was calculated from three replication of each location.

Number of productive tillers in Karang Agung was ranged from 9 to 23, while in Belandean ranged from 15 to 20. Average number of tillers ranged from 14 to 22. Number of tiller of INPARA 9 was relatively low, despite having high grain yield. Otherwise, number of tillers of IR 42 was higher but the grain yield was low. It is may be compensation of asymilate partition from number of tillers to other yielding components, which affects grain yield.

Number of filled grain in Karang Agung and Belandean is quite large. Average number of filled grain was ranged from 114 to 175 grains per panicle (Table 3). Average number of unfilled grains was low. In general, the size of weight of 1000 grains of breeding lines tested (swampy rice) was smaller than irrigated varieties (<26 grams). Based on these traits, in general the lines tested adapt well in tidal swamp land.

Relationship between Traits

The rank correlation between LBS, and grain yield and yield components, plant height, and time of 50% flowering was shown in Table 4. The correlation between grain yield and leaf bronzing symptom was negative and significant with r = -0.537 (Table 4). The coefficient of correlation was medim. There is a strong correlation between LBS and grain yield as seen in this study at 60 DAS and several others (Audebert & Fofana, 2009; Audebert & Sahrawat, 2000; Elec *et al.*, 2013; Onaga, Edema, & Asea, 2012). However, in some other studies no significant correlation between LBS and grain yield was observed (Nozoe *et al.*, 2008; Sahrawat *et al.*, 1996) as seen at 40 and 80 DAS. Level of correlation between the two traits is likely to depend on stress intensity, testing condition, and type of varieties used. When the stress level is moderate, there is no strong relationship between LBS and yield (Audebert & Fofana, 2009). Stress level was rather high with regards to the LBS of the susceptible variety (IR64) which reached the score of 6 (Sikirou *et al.*, 2016). On average, in Fe-toxic soils one unit increase in LBS was related to a yield decrease of about 20%.

Table 4. Correlation of LBS and grain yield, yield component, plant height, and time of 50% flowering

Traits	No. of tiller	Flower	Filled grain	Unfilled grain	W1000	Yield	LBS
Plant Height	0.313*	-0.701**	0.126	0.453**	-0.017	-0.351**	0.529**
No. of tiller		-0.402**	-0.248	0.245	-0.434**	-0.287*	0.308*
Flower			-0.049	-0.303*	0.253	0.510**	-0.588**
Filled grain				0.011	-0.046	0.365**	0.000
Unfilled grain					-0.137	-0.305*	0.329*
W1000						0.185	-0.445**
Yield							-0.537**

Correlation between plant height, number of productive tillers, and unfilled grain and LBS was positive and significant with low-medium of coefficient of correlation. Time of 50% flowering and weight of 1000 grains have significant and negative correlation with LBS.

CONCLUSION

There is six lines have consistency high grain yield and LBS score in two locations, that are (1) B13586E-KA-9-B; (3) B13988E-KA-20, (8) B13983E-KA-13-3, (10) B13983E-KA-13-1, (14) B13925E-KA-46, (17) B13926E-KA-1 with LBS score 3 - 5. Two lines have high yield, but are not consistent with LBS score, that were (21) B14039E-KA-1 and (22) B14009E-KA-39.

There is sufficient evidence to show that the grain yield is negatively correlated to LBS. This relation should be exploited in breeding. LBS is a key secondary trait as it fulfills all the requirements necessary to use it in breeding programs.

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