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Identification of Resistance of Local Rice Genotypes from Solok Selatan, West Sumatra to Leaf Blast (*Magnaporthe oryzae*) and Iron (Fe)Toxicity

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Abstract. *Rice production in acidic soils is often limited by leaf blast disease and iron (Fe) toxicity. This study aimed to identify local rice genotypes cultivated in Solok Selatan that are tolerant to leaf blast disease and iron stresses at the vegetative stage. Ten rice genotypes, consisting of six local genotypes and four comparison genotypes, were tested under three levels of soil Fe content (11,393.12 ppm, 16,781.83 ppm, and 18,699.25 ppm) using a Completely Randomized Design with three replications. The observed variables were number of tillers, root length, leaf blast score, and Fe toxicity score. The results showed that Batang Piaman had the highest number of tillers (72.00), while Guliang Tandai Merah and Batu Hampar Putih had the longest roots (50.67 cm and 49.78 cm). Guliang Tandai Merah had the lowest leaf blast score (2.89), and together with Batang Piaman, also showed low Fe toxicity scores (3.56 and 3.22), indicating good tolerance. In contrast, Simauang and IR64 were the most susceptible against iron toxicity compared to other rice genotypes. Principal Component Analysis (PCA) explained 81.80% of the total variation and placed Batang Piaman and Cilamaya Muncul in the quadrant of high tolerance and good agronomic traits. Cluster analysis grouped the genotypes into three major clusters, with Guliang Tandai Merah and Batu Hampar Putih forming a distinct group based on strong root traits. Although no genotype was completely resistant, Batang Piaman and Guliang Tandai Merah are promising candidates for breeding programs targeting leaf blast and Fe toxicity tolerance.*
Keywords: *Fe toxicity; genotype; leaf blast disease; local rice; multivariate.*

Type of the Paper: Regular Article.

1. Introduction

Rice (*Oryza sativa* L.) is a staple food crop that plays a vital role in meeting the food needs of many countries, including Indonesia [1]. As the population grows, the demand for staple foods, especially rice, also increases [2]. Rice consumption of the Indonesian population in 2024 was 79.007 kg per capita per year, experiencing a decline of 1.75% compared to 2023 [3]. To meet this demand, developing rice varieties that adapt well to different environmental conditions and produce high yields is essential [4]. Superior rice varieties that are adaptable and resistant to pests and diseases play a key role in increasing productivity [5]. One way to achieve this is by exploring, selecting, identifying, and testing the resistance of local rice genotypes in various regions. This helps ensure the availability of genetic resources or rice germplasm, especially from local varieties [6].

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Leaf blast disease and iron (Fe) toxicity are among the key limiting factors that reduce rice production. Leaf blast is a common and destructive disease that frequently damages rice crops and causes significant losses [7]. Blast disease, one of the major rice diseases worldwide, is caused by the fungus *Magnaporthe oryzae* [8]. *M. oryzae* can infect rice plants during vegetative and generative growth stages [9]. It causes characteristic spindle-shaped or elliptical gray-green lesions with brown margins on rice leaves, which can expand and lead to blight or plant death [10].

In addition to biotic stress, abiotic stress like Fe toxicity is also a limiting factor in achieving optimal rice production [11]. Fe is a vital micronutrient required in trace amounts that significantly contributes to chlorophyll formation, metabolic processes, and overall plant development, though excessive levels may lead to toxicity [12]. Although Fe is the fourth most abundant element in the earth’s crust, it can lead to serious toxicity in plants, disrupting germination, metabolic functions, and overall growth [13]. Fe toxicity in rice leads to significant disruptions in plant growth and yield [14]. Rice productivity could decline significantly due to Fe toxicity, which disrupts plant growth, photosynthesis, and yield by causing excessive accumulation of Fe^{2+} in tissues [15].

Solok Selatan Regency in West Sumatra Province has promising potential in developing local rice genotypes. According to previous findings by [6,16], an exploration effort successfully identified 19 local rice genotypes from the region. It is important to conduct resistance tests against biotic stress (leaf blast disease) and abiotic stress (Fe toxicity) to determine which genotypes are resistant or tolerant. Based on this, the study examines the resistance of Solok Selatan local rice genotypes to leaf blast and Fe toxicity during the vegetative phase. This research aimed at identifying local rice genotypes from Solok Selatan, West Sumatera that show tolerance to leaf blast disease and Fe toxicity during vegetative growth stage.

2. Materials and Methods

2.1. Time and place

The research was conducted from April to June 2024 on a farmer's land in Jorong Mato Aie, Nagari Bomas, Sungai Pagu District, Solok Selatan Regency, West Sumatra, at 455.9 masl.

2.2. Plant Genetic Materials

The materials used in this study were six local rice genotypes from Solok Selatan, which were the results of molecular testing conducted at the Plant Breeding Laboratory, Faculty of Agriculture, Andalas University, namely: Simauang, Batu Hampar Putiah, Padi 2000, Marleni, Rambutan, and Guliang Tandai Merah; four comparison genotypes: Batang Piaman (blast-resistant), Cisokan (blast-susceptible), Cilamaya Muncul (Fe-tolerant), and IR 64 (Fe-sensitive) were local rice genotypes from Solok Selatan (Table 1). The genetic materials used were selected based on molecular testing conducted at the Plant Breeding Laboratory, Faculty of Agriculture, Andalas University. Other materials, such as fertilizer (TSP, Urea, KCL fertilizer, and manure), natural blast inoculum, molluscicide, and pesticides were also used in present study.

Table 1. Local and comparison rice genotypes used in the study

Category	Genotype	Role
Local genotypes	Simauang (G1)	Local genotype
	Batu Hampar Putih (G2)	Local genotype
	Padi 2000 (G3)	Local genotype
	Marleni (G4)	Local genotype
	Rambutan (G5)	Local genotype
	Guliang Tandai Merah (G6)	Local genotype
Comparison genotypes	Batang Piaman (G7)	Blast-resistant
	Cisokan (G8)	Blast-susceptible
	Cilamaya Muncul (G9)	Fe-tolerant
	IR64 (G10)	Fe-sensitive

2.3. Experiment procedures

This study used a Completely Randomized Design (CRD) with two factors. The first factor was the total Fe content in the soil, consisting of three levels: 11,393.12 ppm, 16,781.83 ppm, and 18,699.25 ppm. The second factor was the genotype, which included ten rice genotypes: Batu Hampar Putih, Guliang Tandai Merah, Marleni, Padi 2000, Simauang, Rambutan, Batang Piaman, Cisokan, Cilamaya Muncul, and IR 64.

Each treatment combination was replicated three times, resulting in 90 experimental units. Every experimental unit consisted of 10 polybags/plants, bringing the overall research population to 900 plants. Sampling for observation was conducted using a combination of purposive and random sampling. Sampling locations were first selected purposively based on habitat characteristics, and individual plots within each location were then selected randomly. Observations were carried out on all plants within each designated experimental unit. The variables observed included leaf blast disease score, Fe toxicity score, number of maximum tillers, root length during the panicle initiation stage (Stage 5), and total Fe content in both shoot and root tissues at Stage 5.

Inoculation of blast disease in the tested rice genotypes was carried out naturally, by using surrounding paddy field rice plants as spreader plants [5]. The inoculum consisted of rice plants infected with blast disease from around the research site. These infected plants were cut into pieces and distributed around each clump of the tested plants. The assessment and observation of damage caused by blast disease were based on the scale and criteria issued by Biodiversity International, IRRI and WARDA [17]. The blast disease scale can be seen in Table 2.

Table 2. Leaf blast disease severity scale

Scale	Description of symptoms on local rice genotypes
0	No visible symptoms
1	Presence of brown spots or specks the size of a pinhead
2	Greyish necrotic spots, round to slightly elongated (1–2 mm), brown margins, typically on lower leaves
3	Typical blast lesions (1–2 mm), round to slightly oval, on upper leaves
4	Blast lesions ≥ 3 mm, with affected area < 4% of total leaf area
5	Blast affects 4–10% of total leaf area
6	Blast affects 11–25% of total leaf area
7	Blast affects 26–50% of total leaf area
8	Blast affects 51–75% of total leaf area
9	More than 75% of leaf area affected

Resistance categories and virulence analysis were determined based on the standard scale of Biodiversity International, IRRI, and WARDA [17], as follows:

0–2 = Resistant (R),
3 = Moderately resistant (MR),
4 = Moderately susceptible (MS),
5–9 = Susceptible (S).

For the virulence and virulence analysis of *M. oryzae* pathogen races:

Virulent = if the response of the local genotypeis susceptible or moderately susceptible;

Avirulent = if the response of the local genotype is resistant or moderately resistant.

The appearance of plants suffering from Fe toxicity was observed during the maximum tillering stage and the primordia stage. The observations were categorized based on the Fe toxicity symptom scale released by Biodiversity International, IRRI and WARDA [17], as presented in Table 3.

Table 3. Scale of symptoms in plants experiencing Fe toxicity

Scale	Description of symptoms in local rice genotypes
1	Growth and tillering are nearly normal
2	Growth and tillering are nearly normal, with reddish-brown or orange spots at the tips of older leaves
3	Growth and tillering are nearly normal, older leaves are reddish-brown, purple, or yellow-orange
5	Growth and tillering are inhibited; many leaves change colour
7	Growth and tillering stop, most leaves change colour and die
9	Almost all plants die

Scoring for Fe toxicity was conducted weekly until the plants reached phase 5 or the booting stage (8 weeks after planting). The scoring of Fe toxicity symptoms was performed on fully developed rice leaves. Observations were also carried out on the Fe content in the shoots and roots after the plants entered the booting stage (phase 5). Tissue analysis was conducted at the BSIP Laboratory – Sukarami, West Sumatra Province. Meanwhile, maximum tillering was assessed at the booting stage by counting all tillers present in each plant clump within the experimental unit.

2.4. Data analysis

The collected data were analyzed using Analysis of Variance (ANOVA) to determine significant differences among rice genotypes and Fe treatments for each observed variable (number of tillers, root length, leaf blast score, and Fe toxicity score). When significant effects were detected, Tukey's HSD test at the 5% level ($p < 0.05$) was applied to compare treatment means. Pearson correlation analysis was conducted to examine relationships among variables. Principal Component Analysis (PCA) was employed to reduce dimensionality and visualize varietal distribution in a biplot. Furthermore, hierarchical cluster analysis using Euclidean distance and the Ward linkage method grouped the ten rice genotypes based on agronomic and physiological similarities.

3. Results and Discussion

Fig. 1 shows all paddy plants with recorded morphological characteristics used in this study. The overall trend indicated that higher Fe content in the soil was associated with an increase in the number of tillers, with mean values increasing from 53.13 at 11,393.12 ppm to 66.57 at 18,699.25 ppm (Table 4). At the highest Fe level (18,699.25 ppm), Cilamaya Muncul produced the highest number of tillers (82.67), followed by Batang Piaman (79.33) and Rambutan (76.67). In contrast, Batu Hampar Putih and Guliang Tandai Merah consistently exhibited the lowest tiller numbers across all Fe levels, ranging from 31.00 to 56.33. Among all rice genotypes, Batang Piaman (mean: 72.00 ppm) and Cisokan (mean: 70.34 ppm) produced a high number of tillers under the present experimental conditions, although confirmation of their stability requires testing across different environments and growing seasons. These findings align with those of Nurhasanah et al. [18], who reported wide phenotypic variation in upland rice, with tiller numbers ranging from 2 to 66.

Table 4. Number of tillers produced by rice genotypes under different soil Fe contents (ppm)

	Soil Fe content (ppm)			
Genotype	11,393.12	16,781.83	18,699.25	Mean
Batu Hampar Putih (G1)	31.00^{l}	56.33^{g-j}	49.33^{jk}	45.55
Guliang Tandai Merah (G2)	33.00^{l}	41.00^{kl}	53.33^{h-k}	42.44
Marleni (G3)	53.67^{h-k}	60.00^{e-j}	61.33^{e-j}	58.33
Padi 2000 (G4)	53.66^{h-k}	63.33^{e-i}	69.00^{c-g}	61.99
Simauang (G5)	52.33^{i-k}	73.00^{a-e}	62.67^{e-i}	62.67
Rambutan (G6)	52.00^{i-k}	72.67^{a-e}	76.67^{a-d}	67.11
Batang Piaman (G7)	67.67^{c-g}	69.00^{c-g}	79.33^{a-c}	72.00
Cisokan (G8)	64.67^{d-i}	84.67^{a}	61.67^{e-j}	70.34
Cilamaya Muncul (G9)	57.00^{f-j}	67.33^{c-g}	82.67^{ab}	69.00
IR64 (G10)	66.33^{c-h}	67.33^{c-g}	69.67^{b-f}	67.78
Mean	53.13	65.47	66.57	

Note: The values followed by different superscript letters within each column indicate significant differences among genotypes at the p < 0.05 level based on ANOVA and Tukey post-hoc test.

Fig. 1. Paddy plants with recorded morphological characteristics used in this study

An upward trend was observed, with mean root lengths increasing from 36.97 cm at 11,393.12 ppm to 43.07 cm at 18,699.25 ppm (Table 5). Among the genotypes, Batu Hampar Putih and Guliang Tandai Merah had the longest roots under high Fe conditions, reaching 53.33 cm and 42.33 cm, respectively. These two genotypes also exhibited the highest mean values for total root length, 49.78 cm for Batu Hampar Putih and 50.67 cm for Guliang Tandai Merah. On the other hand, IR64 and Cisokan consistently produced shorter roots across all Fe treatments, with mean lengths below 34 cm. Notably, Batang Piaman also exhibited limited root elongation, particularly under low Fe conditions (26.00 cm). These variations highlight the importance of genotype in determining root response to soil Fe content. The statistical analysis confirmed that differences in root length observed between rice genotypes were significant. Longer root systems play a crucial role in enhancing nitrogen uptake, which supports stronger seedling growth [19]. Vigorous root development and greater root length are key factors in improving the absorption of macro- and micronutrients during early plant growth, especially under low soil fertility conditions [20]. Therefore, modifying root length and architecture can significantly improve a plant's ability to explore the soil, thereby increasing water and nutrient uptake, stress tolerance, and overall crop productivity [21].

Table 5. Root length at the vegetative stage under different soil Fe contents (ppm)

Genotype	Soil Fe content (ppm) 11,393.12	 16,781.83	 18,699.25	Mean
Batu Hampar Putih (G1)	46.00^{a-e}	50.00^{ab}	53.33^{ab}	49.78
Guliang Tandai Merah (G2)	52.00^{a-c}	57.67^{a}	42.33^{b-f}	50.67
Marleni (G3)	35.67^{d-h}	38.00^{c-h}	37.67^{c-h}	37.11
Padi 2000 (G4)	40.67^{b-f}	47.33^{a-d}	49.00^{a-c}	45.67
Simauang (G5)	37.67^{c-h}	29.33^{g-i}	40.00^{b-f}	35.67
Rambutan (G6)	33.33^{f-i}	35.67^{d-h}	49.33^{a-c}	39.44
Batang Piaman (G7)	26.00^{i}	42.67^{b-f}	43.33^{a-f}	37.33
Cisokan (G8)	28.67^{hi}	33.33^{f-i}	38.67^{c-g}	33.56
Cilamaya Muncul (G9)	40.33^{b-f}	46.33^{a-e}	41.00^{b-f}	42.56
IR64 (G10)	29.33^{g-i}	35.00^{e-h}	36.00^{d-h}	33.44
Mean	36.97	41.53	43.07	

Note: The values followed by different superscript letters within each column indicate significant differences among genotypes at the $p < 0.05$ level based on ANOVA and Tukey post-hoc test.

The mean leaf blast disease severity scores increased slightly with rising Fe levels, from 4.07 at 11,393.12 ppm to 4.73 at 18,699.25 ppm, indicating that higher Fe availability may be associated with greater disease severity (Table 6). Rice plants cultivated with elevated iron levels exhibited greater resistance to leaf blast, developing fewer lesions than those grown under normal conditions [22]. Exposure of rice plants to elevated iron levels strengthens their defence against infection by *M. oryzae*, the fungus responsible for blast disease [23]. According to the disease scale, leaf blast disease severity scores correspond to moderate symptoms, ranging from typical lesions to blast affecting up to 25% of the total leaf area. Simauang exhibited the highest susceptibility to leaf blast disease with a mean score of 7.56, indicating that 26–50% of its leaf area was affected by the infection. Other moderately susceptible genotypes included Padi 2000 (5.89), Cisokan (5.67), and Rambutan (5.11), all of which showed symptoms within the 4–25% damage range. In contrast, Guliang Tandai Merah recorded the lowest mean score (2.89), followed by Batang Piaman (3.22), Cilamaya Muncul (3.22), and IR64 (3.11), indicating milder symptoms of infection with only small lesions or less than 4% of the leaf area affected. All observed differences in blast severity were statistically significant. Supporting this observation, a study of 201 leaf blast isolates collected from various Indonesian rice ecosystems (upland, lowland, and swampy) revealed diverse virulence patterns, leading to the establishment of a new differential system using 25 differential genotypes and 27 standard isolates [24]. The pathogen, which is present in over 85 rice-producing countries, has prompted the identification of more than 100 resistance genes globally [25]. However, recent findings from West Java highlight that despite widespread fungicide use, blast disease remains severe, suggesting the possible emergence of leaf blast resistance to isoprothiolane and underscoring the need for updated management strategies [26].

Table 6. Rice leaf blast score under the different soil Fe contents (ppm)

	Soil Fe content (ppm)			
Genotype	11,393.12	16,781.83	18,699.25	Mean
Batu Hampar Putih (G1)	3.00^{ef}	4.00^{c-f}	3.00^{ef}	3.33
Guliang Tandai Merah (G2)	2.33^{f}	3.67^{b-f}	2.67^{f}	2.89
Marleni (G3)	4.33^{c-f}	5.00^{a-d}	5.00^{b-f}	4.78
Padi 2000 (G4)	4.67^{b-f}	6.33^{a-d}	6.67^{a-c}	5.89
Simauang (G5)	7.67^{ab}	6.67^{a-c}	8.33^{a}	7.56
Rambutan (G6)	4.33^{c-f}	5.00^{b-f}	6.00^{a-e}	5.11
Batang Piaman (G7)	2.67^{f}	3.33^{d-f}	3.67^{c-f}	3.22
Cisokan (G8)	6.67^{a-c}	5.33^{a-f}	5.00^{b-f}	5.67
Cilamaya Muncul (G9)	2.33^{f}	3.00^{ef}	4.33^{c-f}	3.22
IR64 (G10)	2.67^{f}	4.00^{c-f}	2.67^{f}	3.11
Mean	4.07	4.63	4.73	

Note: The values followed by different superscript letters within each column indicate significant differences among genotypes at the $p < 0.05$ level based on ANOVA and Tukey post-hoc test.

Although the mean scores increased slightly from 4.17 at 11,393.12 ppm to 4.53 at both 16,781.83 and 18,699.25 ppm, the differences were not substantial (Table 7). According to the Fe toxicity scale, these average scores correspond to moderate symptoms, where growth and tillering begin to be inhibited and many leaves showed discoloration (score 5). The genotype IR64 showed the highest sensitivity, with a mean score of 6.11, indicating visible stress symptoms such as inhibited growth and widespread leaf colour changes. Other susceptible genotypes included Simauang (5.67) and Marleni (5.22), which also exhibited moderate to severe symptoms. In contrast, Batang Piaman (3.22), Guliang Tandai Merah (3.56), and Rambutan (3.44) recorded lower mean scores, indicating minimal physiological disturbance, with symptoms limited to older leaves showing colour changes without major growth inhibition. These genotypes demonstrated relatively better tolerance to Fe toxicity. The observed differences in Fe toxicity responses among the genotypes may be partly explained by genetic factors, as Nugraha et al. [27] identified Single Nucleotide Polymorphism marker TBGI380435 on chromosome 9 to be significantly associated with leaf bronzing and relative shoot weight, traits indicative of tolerance to Fe toxicity. Supporting this, several local Kalimantan rice cultivars such as Amas, Pandan Ungu, and Kambang were also identified as potential candidates for Fe toxicity tolerance, exhibiting favourable morphophysiological traits and elevated antioxidant enzyme activities under high-Fe stress conditions [28]. Consistent with these findings, rice lines derived from local Fe-tolerant cultivars such as Cekau and Karya demonstrated stable performance under high-Fe conditions across various locations and seasons, with tolerant lines remaining unaffected by seasonal variations and showing improved productivity when treated with 200 kg ha^{-1} of salt to enhance root quality [29].

Table 7. Fe toxicity score of rice genotypes under the different soil Fe contents (ppm)

	Soil Fe content (ppm)			
Genotype	11393.12	16781.83	18699.25	Mean
Batu Hampar Putih (G1)	$3.67^{a\text{-}c}$	$5.00^{a\text{-}c}$	$4.33^{a\text{-}c}$	4.33
Guliang Tandai Merah (G2)	$2.67^{a\text{-}c}$	3.67^{ab}	$4.33^{a\text{-}c}$	3.56
Marleni (G3)	$4.33^{a\text{-}c}$	6.33^{ab}	$5.00^{a\text{-}c}$	5.22
Padi 2000 (G4)	4.33^{a}	$5.00^{a\text{-}c}$	$5.67^{a\text{-}c}$	5.00
Simauang (G5)	$5.67^{a\text{-}c}$	$5.00^{a\text{-}c}$	$6.33^{a\text{-}c}$	5.67
Rambutan (G6)	$3.67^{a\text{-}c}$	$3.67^{a\text{-}c}$	$3.00^{a\text{-}c}$	3.44
Batang Piaman (G7)	$3.00^{a\text{-}c}$	$3.00^{a\text{-}c}$	3.67^{bc}	3.22
Cisokan (G8)	5.00^{a}	3.67^{bc}	3.67^{a}	4.11
Cilamaya Muncul (G9)	$3.00^{a\text{-}c}$	4.33^{bc}	3.00^{ab}	3.44
IR64 (G10)	$6.33^{a\text{-}c}$	5.67^{bc}	6.33^{a}	6.11
Mean	4.17	4.53	4.53	

Note: The values followed by different superscript letters within each column indicate significant differences among genotypes at the $p < 0.05$ level based on ANOVA and Tukey post-hoc test.

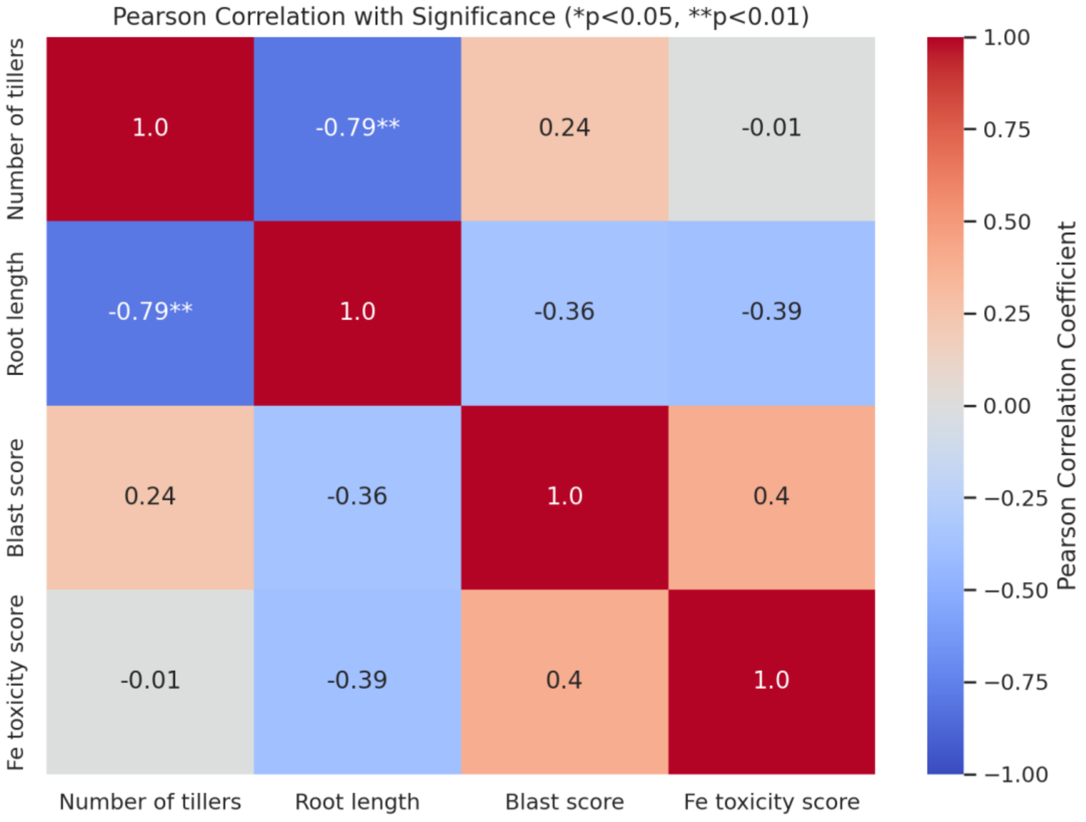

Fig. 2. Pearson correlation matrix among agronomic and physiological traits of local rice genotypes

Pearson correlation analysis revealed a strong negative and statistically significant correlation between the number of tillers and root length ($r = -0.79$; $p < 0.05$), indicating that as tiller number increased, root length tended to decrease (Fig. 2). This result suggested that an increase in tiller production led to increase energy and nutrient demands for shoot development, thereby limiting allocation to root growth [30]. The root and tiller systems in rice are known to be physiologically interdependent, with nodal roots forming the primary framework of the root structure [31]. Furthermore, early-developing tillers generally produce more and longer roots compared to later tillers, which may explain why high-tillering genotypes often exhibit shorter root systems [32]. The correlation between root length and Fe toxicity score was also negative ($r = -0.39$; $p > 0.05$), suggesting that genotypes with longer roots may exhibit better tolerance to Fe toxicity, although this relationship was not statistically significant. A moderate positive correlation was observed between blast score and Fe toxicity score ($r = 0.40$; $p > 0.05$), indicating that rice genotypes susceptible to blast also tended to be sensitive to Fe toxicity; however, this relationship was likewise not significant. Very weak correlations were found between the number of tillers and blast score ($r = 0.24$; $p > 0.05$), and between tiller number and Fe toxicity score ($r = -0.01$; $p > 0.05$); neither of which was statistically significant.

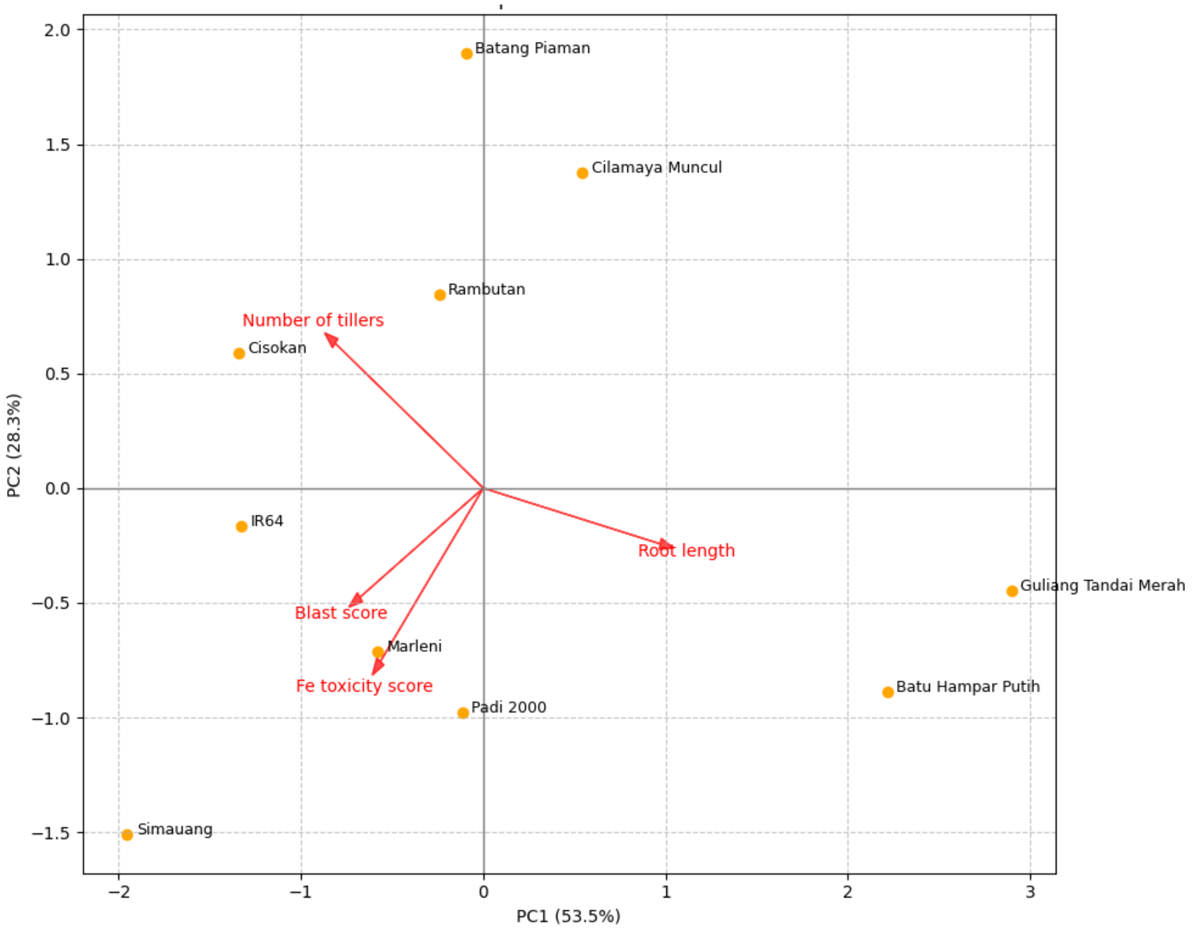

Fig. 3. PCA biplot of ten rice genotypes based on agronomic and physiological traits

The biplot from the PCA illustrated the distribution of ten rice genotypes based on four agronomic and physiological traits: tiller number, root length, blast score, and Fe toxicity score (Fig. 3). The first two principal components (PC1 and PC2) explained 81.8% of the total variation in the dataset, with PC1 accounting for 53.5% and PC2 for 28.3%. The direction of the vectors also indicated that tiller number was negatively correlated with root length, while blast score and

Fe toxicity score were positively correlated. These results supported the identification of genotypes with superior combinations of agronomic and stress tolerance traits. Additionally, previous studies have suggested that high Fe availability may enhance rice resistance to leaf blast by increasing defense gene expression, phytoalexin production, and ferroptosis near infection sites, indicating a potential link between Fe homeostasis and immune response [23].

The dendrogram from the hierarchical cluster analysis grouped the ten rice genotypes into three main clusters based on Euclidean distance coefficients ranging from 0.27 to 0.75, which reflect moderate to high dissimilarity among genotypes in terms of agronomic and physiological traits (Fig. 4). The cluster analysis identified distinct groups of rice genotypes with complementary trait profiles, revealing which genetically distant parents should be crossed in future breeding programs to efficiently combine high yield with disease and stress tolerance [5]. These clustering patterns provide valuable insight for future breeding programs. Specifically, genotypes from different clusters can be selected as diverse parental lines to maximize heterosis and combine desirable traits. For example, crossing Guliang Tandai Merah or Batu Hampar Putih (root vigor and Fe tolerance) with Batang Piaman or Cilamaya Muncul (disease resistance and high tiller number) could generate progenies with both strong root systems and improved blast and Fe tolerance. Thus, the results highlight the importance of using genetically and phenotypically diverse parents to develop multi-stress-tolerant and high-yielding rice genotypes suitable for acidic and Fe-toxic soils.

The first cluster consisted of Padi 2000, Marleni, Simauang, and IR64, which exhibited close Euclidean distances and shared similar characteristics. The second cluster included Cisokan, Rambutan, Cilamaya Muncul, and Batang Piaman, which were grouped together due to their relatively high pattern similarity. Meanwhile, the third cluster comprised Guliang Tandai Merah and Batu Hampar Putih, which formed a distinct group and were clearly separated from the other clusters. These groupings reflected consistent trends observed in the individual trait analyses. Supporting this result, previous studies using cluster analysis of 18 local rice genotypes from Solok Selatan reported genetic similarity ranging from 27% to 64%, with Rambuman and Redek Sangir showing the highest similarity at 64% [6]. In addition, based on vegetative morphological traits, the genotypes demonstrated genetic similarity between 36% and 75%, with six genotypes, Redek Putiah, Harum Manis, Simauang, Batu Hampar Kuning, Batu Hampar Tinggi, and Padi 2000 sharing the highest similarity at 75% [16].

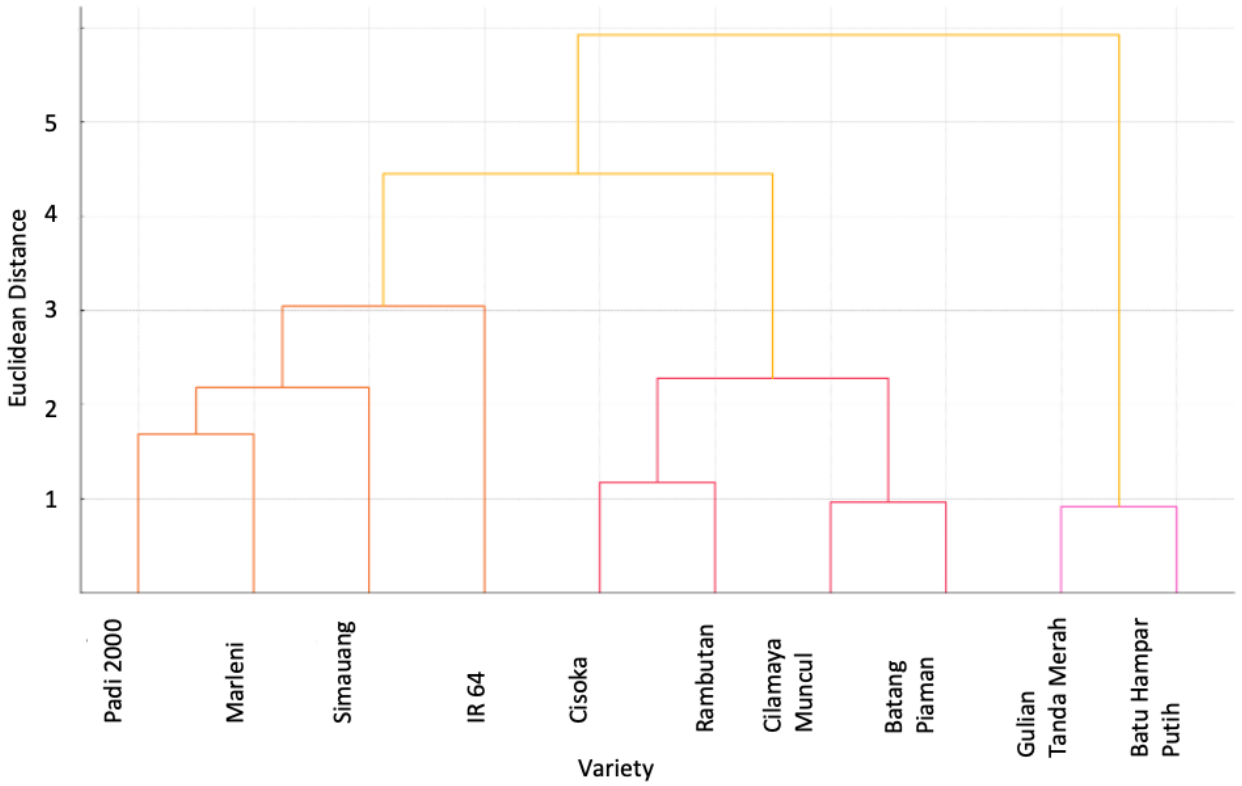

Fig. 4. Hierarchical clustering dendrogram of ten rice genotypes based on agronomic and physiological traits

4. Conclusions

In conclusion, none of the tested rice genotypes exhibited complete resistance to leaf blast disease or full tolerance to Fe toxicity (score 0–1). Among the ten tested genotypes, Guliang Tandai Merah and Batang Piaman demonstrated strong tolerance to both stresses, as evidenced by their low blast and Fe toxicity scores. These genotypes consistently maintained good performance under elevated Fe conditions and showed resistance to leaf blast infection, making them promising candidates for cultivation in stress-prone acidic soils. The local rice genotypes from Solok Selatan possess potential as genetic resources (germplasm) for developing improved rice genotypes. Further research is needed to identify the specific blast races present in Solok Selatan, as even the comparison genotypes were affected, with some showing higher disease scores. In addition, further investigation is required on planting methods or cultivation techniques to minimize the impact of blast and Fe toxicity stress. Since no genotype in this study showed complete resistance to both leaf blast disease and Fe toxicity, the most effective breeding approach would be to combine gene pyramiding and marker-assisted selection (MAS). This strategy would allow breeders to integrate resistance genes for blast disease and tolerance genes for Fe toxicity from different parental lines, such as Batang Piaman and Guliang Tandai Merah, into a single genotype. The use of recurrent selection and multi-environment evaluation would further help in identifying stable lines that consistently perform well under both stresses. This integrated approach is expected to accelerate the development of rice genotypes that are not only high yielding but also tolerant to multiple stress conditions.

Despite the useful initial insights into the tolerance of local rice genotypes from Solok Selatan to leaf blast disease and iron (Fe) toxicity, this study has some notable limitations. The experiment involved only ten genotypes, conducted in a single location and season, which means the findings may not fully reflect how these genotypes would perform under different environmental or soil conditions. Observations were limited to the vegetative stage, even though both Fe toxicity and leaf blast may influence plant growth differently during flowering or grain development. Since natural inoculation was used for the blast test, infection levels might not have been consistent, and without identifying the pathogen races, it is unclear how specific the resistance responses were. In addition, yield-related data were not collected, making it difficult to assess the practical benefits of the tolerant genotypes. For future research, it is recommended to test a wider range of genotypes across several locations and growing seasons, apply controlled inoculation with identified blast races, and include molecular and physiological evaluations. Extending the study to the reproductive stage and measuring yield performance would also help clarify how well these genotypes perform under actual field conditions.

Abbreviations

ANOVA	Analysis of Variance
DMRT	Duncan’s Multiple Range Test
Fe	Iron
PCA	Principal Component Analysis
PC	Principal Component
R	Pearson Correlation Coefficient
CRD	Completely Randomized Design
HSD	Honestly Significant Difference
Masl	meters above sea level
BI	Bioversity International
IRRI	International Rice Research Institute
WARDA	West Africa Rice Development Association
R	Resistant
MR	Moderately Resistant
MS	Moderately Susceptible
S	Susceptible
Ppm	parts per million

Data availability statement

The data supporting this study are available from the authors upon reasonable request.

Credit authorship contribution statement

Vera Septaria: Conceptualization, Data curation, Formal analysis, Funding acquisition, Investigation, Methodology, Project administration, Resources, Software, Supervision, Validation, Visualization, Writing – original draft, Writing – review and editing. **Musliar Kasimb**, **Irfan Suliansyah**, **Auzar Syarif**, **Juniarti**: Methodology, Supervision, Validation, Writing –

review.

Declaration of Competing Interest

The authors confirm that there are no financial or personal conflicts that could have affected the objectivity or integrity of the research presented in this manuscript.

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