Screening of rice germplasm for blast resistance in Nigeria

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Abstract. Gabriel MG, Alhasan U, Mary Y, Munsur Y, Olufunmilayo A. 2022. Screening of rice germplasm for blast resistance in Nigeria. Asian J Agric 6: 1-6. Rice blast (Magnaporthe oryzae T.T. Hebert) M.E. Barr) is an important destructive disease of rice that can lead to 80% yield loss. Germplasm responds differently to blast fungus. This study aimed to screen rice germplasm for blast resistance in Nigeria. The four genotypes, namely Institute for Research in Tropical Agriculture, France (IRAT) 109, JAMILA, Federal Agriculture Research Oryza (FARO) 52, and FARO 66 were evaluated in a completely randomized design with three replications in the screen house of the Department of Crop Protection, Institute for Agricultural Research Samaru, Nigeria. Data were collected on plant height, the number of plants infected with a blast, seedling vigour, tillering ability, blast disease score, and leaf blast estimated. Analysis of variance showed a high significant difference (P ≤ 0.01) for seedling vigour (0.03**) and disease index (17.24**) while significant (P ≤ 0.05) variation was observed for a number of the leaf (3.79*). In contrast, there was no significant (P > 0.05) variation for plant height and tillering ability. The highest PCV (Phenotypic Coefficient of Variance) and GCV (Genotypic Coefficient of Variance), also broad-sense heritability was observed in leaf blast. IRAT 109 (0.6) depicted a high resistance, JAMILA moderately susceptible (Blas score 4.0) while FARO 52 (7.3) and FARO 66 (6.1) were susceptible. A significant difference among genotypes implies sufficient variation among genotype screened, suggesting that progress can be made following selection.

Keywords: Magnaporthe oryzae, Oryza sativa, resistance, rice, screening

INTRODUCTION

Rice (Oryza sativa L.) with a genome size of 430 mb (2n = 24), is the most widely consumed staple food for a large part of the world’s human population (Amanullah et al. 2016; Perera and Dahanayake 2016). It may have originated in China and is now cultivated all over the world (Smith 2006). Global rice production is estimated to be 755.5 million ton per year, harvested from 162.1 million ha in more than 100 countries with average productivity of 4.7 ton/ha (FAO 2019). In Africa, a total of 14.2 million ha and 17.1 million ha of land area was cultivated with 33.2 million ton and 38.5 million ton harvested in 2018 and 2019, respectively with similar productivity of 2.3 ton/ha. For example, Nigeria had rice production on a land area of 3.3 million ha and 5.3 million ha with 6.8 ton million ton and 8.4 million ton harvested, and a productivity of 2.03 ton/ha and 1.6 ton/ha in 2018 and 2019, respectively (FAO 2018; 2019).

Rice is an important staple food crop for more than half of the world population and it provides 27% of the calories in low and middle-income countries (Patil and Sharanagouda 2017; Susanto et al. 2017; Etsiati 2019; Weerakoon and Somaratne 2020). Therefore, yield loss of rice production represents a significant threat to food security. Furthermore, it is stated that rice production must increase by 40% in 2030 to meet the ever-increasing demand (Khush et al. 2001). Hence population is increasing at an alarming rate, making food security the major challenge in the future.

Disease and pests are among the most important limiting factors that affect rice production. More than 70 diseases carried by fungi, bacterial, viruses or nematodes have been reported on rice and in severe cases, these losses could be up to 70-80% in some rice ecosystems (Deepak and Prasanta 2017). Among rice diseases, a blast is one of the devastating diseases worldwide (Fahad et al. 2019). Its wide destructiveness under conducive conditions results in yield loss ranging from 1-50% in a wide range of environmental conditions (Skamnioti and Gurr 2009). It is indicated that the genetic control of blast resistance is complex due to major and minor genes with complementary or additive effects and their environmental interactions (Zewdu et al. 2018).

Though chemical control has been successful, it adds to the cost of cultivation and contaminates the environment (Nalley et al. 2016). Deployment of host plant resistance genes is considered the best option for managing the disease, most of which are distributed in clusters (Raboin et al. 2016; Bano et al. 2017). The rapid changes that occur in the virulence characteristics of the blast population raise a continuous threat to the effectiveness of existing blast-resistant varieties. For the control of blast, the breeding of resistant varieties is an effective approach to reduce the use of pesticides and minimize rice losses due to this disease.

Continuous studies on blast are important to overcome this disease. Thereby sustaining rice production in the future. Therefore, this study aimed to screen four genotypes of rice germplasm for blast resistance in Nigeria.
MATERIALS AND METHODS

Study site
The research was conducted in 2019 at the Institute for Agricultural Research (IAR) screen house, Ahmadu Bello University Zaria, Kaduna State, located in Samaru on 11°11′N, 7°38′E and 686 m above sea level in the Northern Guinea Savannah Ecological Zone of Nigeria. The area’s average annual rainfall is about 1,058 mm, which is distributed within 160 days (Olanuga 1979).

Plant materials
The plant materials comprised of 4 rice genotypes, namely Institute for Research in Tropical Agriculture, France (IRAT) 109, Federal Agriculture Research Oryza (FARO) 52, and FARO 66 were obtained from African Rice (International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria), and JAMILA was obtained from the Zaria. The Rice blast resistance of each genotype is presented in Table 1.

Procedures
Fungal isolation
Plant samples were collected from a rice blast infested field in Dogarawa, Bomo Village, and Samaru Kaduna State, Nigeria. Diseased leaves and nodes of rice panicles were placed on wet filter papers in a Petri-dish for sporulation (Ou 1985).

Media preparation
Potato Dextrose Agar with streptomycin (PDAs) growth media was used. First, 200 g of sliced peeled potatoes were weighed in 1 l of water and boiled for 30 minutes. It was then filtered out, 20 g of agar and 20 g of Dextrose were then weighed into the solution and mixed well. The media was then autoclaved at 121°C for 15 minutes and left to cool to about 40 °C. It was then dispensed into sterile Petri dishes with a diameter of 9 cm (Ou 1985).

Leaf preparation
Infected leaf samples were cut into small portions and sodium hypochlorite was added to it for 3 min and rinsed 3 times with distilled water (Ou 1985).

Culturing
Leaf samples were placed on the media in a petri-dish in the microflow chamber before being taken to an incubator for observation of blast and viewed under a microscope (7-14 days) (Ou 1985).

Inoculation
The inoculum was harvested from the cultured plate and blended (mixed) in 200 mL of water and the solution was sieved using a muslin cloth. River sand was sieved and sterilized using the oven. It was then used to create injury (rubbing) on the leaf’s surface to aid proper penetration of the inoculum. The inoculum was sprayed on the surface of the plant leaf and the residue was also used to inoculate the soil in the screen house. The inoculum’s strength was determined using a hemocytometer (Gowrisri et al. 2019).

Spore storage and count
The cultured pathogen was sub-cultured into a McCartney bottle using a sterile picking pin. It was then kept for further use to not lose the pathogen (Gowrisri et al. 2019). The inoculum’s strength was determined using a hemocytometer, and the spore count (50,000 spores/mL) was calculated (Smith et al. 1988).

Screening of genotype of rice
The four rice genotypes were screened for blast disease during the dry season of 2019 (February-March). The genotypes were raised in a completely randomized design with three replications in 14 cm diameter wide and 12 cm deep pot. Five seeds of each of the materials were planted in 2 rows of 5 pots each. FARO 52 Plants were used as spreaders and inoculated with conidia harvested from mycelia of a Magnaporthe oryzae (T.T. Hebert) M.E. Barr isolate. The test material (IRAT 109) surrounded 6 stands of susceptible rice cultivar as spreader rows. At the fourth-leaf stage (3-4 weeks after sowing), the seedlings were sprayed with spores of M. oryzae and about 30-40 mL of the spore suspension of the blast pathogen, soil inoculation was done alongside the leaf inoculation. Water was sprayed 3-4 times a day to maintain high humidity. Inoculated seedlings were monitored to develop blast lesions (Gowda et al. 2015). The disease reaction of each genotype was calculated as described by SES IRRI (2013).

Data analysis
The agronomical and physiological data collected were subjected to analysis of variance (ANOVA) using General Linear Model procedure of Statistical Analysis System (SAS 2002). Fisher’s protected least significant difference (LSD) test was used for comparison.

Randomized complete block design (RCBD) linear model: $y_{ijk} = \mu + \alpha_i + \beta_j + e_{ijk}$

Where,
- $y_{ijk}$ = Responds of the experimental $i^{th}$ treatment unit with the $j^{th}$ replicate and $k^{th}$ block.
- $\mu$ = The overall mean
- $\alpha_i$ = Effect of treatment
- $\beta_j$ = The effect of block $j$
- $e_{ijk}$ = Random error
- $i = $ Number treatment unit; $j = $ Number of replication; $k = $ Number of block.

(Kittiwat et al. 2018).
Table 1. Description of four rice genotypes studied (Toungos 2016)

| Characters       | IRAT 109          | FARO 52          | FARO 66          | JAMILA                   |
|------------------|-------------------|------------------|------------------|--------------------------|
| Rice blast resistance | Resistance        | Highly susceptible | Susceptible to blast | Moderately Susceptible to blast |
| Medium maturity  | Medium maturity between 90-100 days | Medium Maturity (100-110) | Medium Maturity (100-110) | Medium maturity between 90-100 days |
| Iron toxicity    | Not resistant to toxicity | Resistant to Iron toxicity | Moderately tolerant to iron toxicity | Not resistant to iron toxicity |
| Yield            | Medium Yielding   | High Yielding    | Medium Yielding  | High Yielding land race   |
| Grain            | Fat white grain   | Moderately long white grain | Medium slender grains | Long White-grain          |
| Submergence      | -                 | Susceptible      | Tolerant         | -                        |

Table 2. Description of the standard evaluation system scale for rice blast disease scoring (SES IRRI 2013)

| Grade | Disease severity                                                                 | Host response           |
|-------|----------------------------------------------------------------------------------|-------------------------|
| 0     | Please say something                                                             | Highly Resistant        |
| 1     | Small brown specks of pin point size                                            | Resistant               |
| 2     | Small roundish to slightly elongated, necrotic gray spots, about 1-2 mm in diameter, with a distinct brown margin. Lesions are mostly found on the lower leaves | Moderately resistant    |
| 3     | Lesion type same as in 2, but significant number of lesions on the upper leaves | Moderately resistant    |
| 4     | Typical susceptible blast lesions, 3 mm or longer infecting less than 4% of leaf area | Moderately Susceptible |
| 5     | Typical susceptible blast lesions of 3mm or longer infecting 4 10% of the leaf area | Moderately Susceptible |
| 6     | Typical susceptible blast lesions of 3 mm or longer infecting 11-25% of the leaf area | Susceptible |
| 7     | Typical susceptible blast lesions of 3 mm or longer infecting 26-50% of the leaf area | Susceptible |
| 8     | Typical susceptible blast lesions of 3 mm or longer infecting 51-75% of the leaf area many leaves are dead | Highly Susceptible |
| 9     | Typical susceptible blast lesions of 3 mm or longer infecting more than 75% leaf area affected | Highly Susceptible |

Phenotypic and genotypic variability

The phenotypic and genotypic coefficient of variation were estimated according to Burton and Devane (1953) as follows:

\[
gCV = \sqrt{\frac{\sigma_g^2}{X^2}} \times 100
\]

Where:
- \( gCV \) = Genotypic coefficient of variation
- \( X \) = Grand mean value of the trait

\[
GCV = \sqrt{\frac{MS_g - MS_e}{r}} \times 100
\]

\[
\sigma_g^2 = \sigma_p^2 + \sigma_e^2
\]

Where:
- \( \sigma_g^2 \) = Genotypic variance
- \( \sigma_p^2 \) = Phenotypic variance
- \( \sigma_e^2 \) = Error variance
- \( MG_g \) = Mean squares of genotypes
- \( MS_e \) = Mean square due to error
- \( r \) = Number of replications

\[
PCV = \sqrt{\frac{\sigma_p^2}{X^2}} \times 100
\]

Heritability

Heritability in broad sense (\( h_b^2 \)) for 5 characters was computed using the formula adopted by Allard (1960) as follows:

\[
h_b^2 = \frac{\sigma_g^2}{\sigma_p^2} \times 100
\]

Where:
- \( h_b^2 \) = Heritability in broad sense
- \( \sigma_g^2 \) = Genotypic variance
- \( \sigma_p^2 \) = Phenotypic variance
RESULTS AND DISCUSSION

Analysis of variance

The result of the analysis of variance (ANOVA) revealed highly significant (P < 0.01) variation for seedling vigour, number of infected leaves and leaf blast and no significant (P < 0.05) difference was depicted by plant height and tillering ability (Table 3).

Estimated variance component

The result of the estimated variance component for genotypic variance range from 0.01 (seedling vigour) to 8.52 (leaf blast) while phenotypic variance range from 0.01 to 11.80 (plant height) (Table 4). The PCV value computed for the 5 traits ranged from 12.83 for seedling vigour to 65.24 for leaf blast while GCV ranged from 3.93 tillering ability to 64.88 leaf blast. The value of the phenotypic coefficient of variation was generally slightly higher than the corresponding genotypic coefficient of variation for all traits studied. High GCV was observed for leaf blast (64.88) and a number of the leaf (59.41) while moderate GCV was observed for seedling vigour (10.14). High PCV was observed for leaf blast (65.24) and a number of the leaf (61.21) while tillering ability (27.90), seedling vigour (12.83) and plant height (13.54) showed moderate PCV (Table 4).

Heritability in broad sense

Broad sense heritability (Hb) estimates the total contribution of genetic variance to total phenotypic variance ranged from 4.52 tillering ability to 98.88 leaf blast. The heritability was high for leaf blast (98.88), a number of leaf (94.20) and seedling vigour (62.50) which might be due to environmental influence on the expression of the traits. On the other hand, low heritability in broad sense was observed for plant height (21.54) and tillering ability (4.52) (Table 4).

Mean performance of genotypes

Plant height has a mean of 25.38 and ranges from 23.88-29.25, seedling vigour has a mean of 0.90 and ranged from 0.8-1.0, tillering ability has a mean of 10.30 and ranged from 6.10-1 2.30, number of leaf has a mean of 2.26 and ranged from 2.10-3.60 while leaf blast has a mean of 4.50 and ranged from 0.60-7.30 (Table 5). The significant difference for the traits studied at the 5% probability level was further confirmed by the mean comparison test using the respective LSD values. The mean performance indicated the different responses to the blast as there was variation.

Discussion

The average Nigerian rice productivity is still very low compared to other rice-producing countries in the world. This is mainly due to insufficient improved rice varieties, disease and other environmental factors affecting rice productivity. As a result, the present study accounted for screening 4 rice genotypes for resistance to rice blast and pattern of genetic variance present in the rice genotype. The presence of highly significant among the genotype for all characters except for tillering ability and plant height that was non-significant implies the presence of considerable variation among the genotype. The GCV values were relatively lesser than PCV for all traits, however, the magnitude of the difference between the PCV and GCV was relatively low for tillering ability, plant height and vegetative vigour. This implies that the marked influence of environmental factors for the phenotypic expression of genotype was low; therefore, there is a higher chance of improving this trait through selection based on the phenotypic value of the traits. On the other hand, the difference in magnitude between the PCV and the GCV was relatively high for the number of leaf and leaf blast (Table 5) (Ikramullah et al. 2011).

| Table 3. Mean squares of rice genotype screened for blast fungus |
|-------------------------------|-----------------|-------------------|-------------------|-----------------|-----------------|
| Source | Degree of freedom | Plant height | Seedling vigour | Tillering ability | Number of leaves affected | Leaf blast |
| Replications | 1 | 1.98 | 0.01** | 9.68 | 0.02 | 0.02** |
| Genotype | 3 | 18.52 | 0.03** | 16.52 | 3.79* | 17.24** |
| Error | 3 | 13.44 | 0.01 | 15.77 | 0.22 | 0.19** |

Note: **: highly significance difference at (P > 0.01) probability level, *: significance difference at (P >0.05) probability level, ns: no significant

| Table 4. Variance component of rice genotype for blast fungus |
|-------------------------------|-----------------|-----------------|-----------------|-----------------|-----------------|
| Traits | Variance component | | | | |
| | $\sigma_g^2$ | $\sigma_p^2$ | GCV % | PCV % | Hb |
| Plant height | 13.44 | 2.54 | 11.80 | 6.28 | 13.54 | 21.54 |
| Seedling vigour | 0.01 | 0.01 | 0.01 | 10.14 | 12.83 | 62.50 |
| Tillering ability | 15.77 | 0.37 | 8.26 | 5.93 | 27.90 | 4.52 |
| Number of leaves affected | 0.22 | 1.79 | 1.90 | 59.41 | 61.21 | 94.20 |
| Leaf blast | 0.19 | 8.52 | 8.62 | 64.88 | 65.24 | 98.88 |
Table 5. Mean performance of rice genotype for blast fungus

| Traits            | Genotype | Mean  | Range          | CV%  |
|-------------------|----------|-------|----------------|------|
| Plant height      | FARO 52  | 23.93 | 23.88-29.25    | 16.96|
|                   | FARO 66  | 23.88 |                |      |
|                   | IRAT 109 | 24.47 |                |      |
|                   | JAMILA   | 29.25 |                |      |
|                   | Mean     | 25.38 |                |      |
|                   | LSD      | 13.7  |                |      |
| Seedling vigour   | FARO 52  | 0.80  | 0.8-1          | 0.01 |
|                   | FARO 66  | 0.80  |                |      |
|                   | IRAT 109 | 1.00  |                |      |
|                   | JAMILA   | 1.00  |                |      |
|                   | Mean     | 0.90  |                |      |
|                   | LSD      | 0.00  |                |      |
| Tiller ability    | FARO 52  | 6.10  | 6.10-12.30     | 38.56|
|                   | FARO 66  | 12.30 |                |      |
|                   | IRAT 109 | 12.00 |                |      |
|                   | JAMILA   | 10.80 |                |      |
|                   | Mean     | 10.30 |                |      |
|                   | LSD      | 12.64 |                |      |
| Number of leaves  | FARO 52  | 3.60  | 2.10-3.60      | 20.85|
| affected          | FARO 66  | 2.90  |                |      |
|                   | IRAT 109 | 2.40  |                |      |
|                   | JAMILA   | 2.10  |                |      |
|                   | Mean     | 2.26  |                |      |
|                   | LSD      | 1.49  |                |      |
| Leaf blast        | FARO 52  | 7.30  | 0.60-7.30      | 9.77 |
|                   | FARO 66  | 6.10  |                |      |
|                   | IRAT 109 | 0.60  |                |      |
|                   | JAMILA   | 4.00  |                |      |
|                   | Mean     | 4.50  |                |      |
|                   | LSD      | 1.40  |                |      |

A high heritability estimate was observed for seedling vigour, a number of leaf and leaf blast. The high estimated heritability value for these traits indicated that the variation observed was mainly under genetic control and was less influenced by the environment. Hence, the possibility of progress from a selection. This may be attributed to the uniform environment in the screen house (Muhder et al. 2020). In general, high heritability was observed for leaf blast, leaves, and seedling vigour. It suggests that selection based on these characters would be effective for future crossing programs. This result agrees with the work of Tuhina-Khatun et al. (2015) and Kamara et al. (2017), who also reported high broad-sense heritability in rice.

Observations recorded 30-40 days after sawing based on leaf blast severity following SES IRRI (2013) scale showed that IRAT 109 is highly resistant and this was visible both in growth and vigour. The resistant ability of these genotypes may be genetics as it suppresses the organism’s development causing these diseases. Although FARO 66 is susceptible, it was less susceptible when compared to FARO 52 which is the most susceptible among the four genotypes. The fungus was visible at 40 days after sawing on the leaves, while JAMILA was moderately susceptible. This result agrees with Spyridon et al. (2009), who reported that varietal differences significantly contributed to the resistance or susceptibility of the rice to leaf blast and also in line with the work of Gbadeyan et al. (2018) who worked on screening of blast and genotype by environment interaction of rice. The different response of the rice genotypes used in this study is important in selecting resistant varieties. These findings inspire further genetic studies to improve the genotypes through hybridization and selection programs.

In conclusion, the study highlighted rice germplasm with blast resistance in Nigeria and significant genetic variations for agronomically important traits, such as seedling vigour, leaf blast, and a number of leaf among the four rice genotypes act as a pointer. Furthermore, the promising genotypes of IRAT 109 exhibited a significant level of resistance than JAMILA, FARO 52, and FARO 66. Hence, IRAT 109 can be considered a candidate for a blast-resistant variety for possible progress.

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