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Original Research Article

Evaluation of forty-five rice (*Oryza species*) accessions for resistance to rice blast (*Magnaporthe oryzae*) disease under natural conditions

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Abstract

The experiments were conducted to investigate the resistance levels among forty-five lowland rice accessions at the Teaching and Research Farm, Federal College of Agriculture, Ishiagu (Latitude 5°56″N and Longitude 7°41″E) Ebonyi State, Nigeria. Forty-five rice accessions were screened for their resistance to the blast disease in row planting during the 2017 and 2019 cropping seasons using Randomised Complete Block Design (RCBD) and were replicated thrice. The data on disease intensity and agronomic performance were subjected to Analysis of Variance and the significant means were separated with the Tukey HSD test at $p < 0.05$. Assessment of blast disease showed that the incidence, severity, and resistance levels varied significantly among rice tested. Accession NG/SA/JAN/023 had the highest disease incidence (59.06%) while accessions NG/SA/DEC/07/0300, TOG 5453, TOG 6804, FARO-22 and FARO-57 had no blast symptoms for the two cropping seasons. The disease severity ranged from 0.00 to 3.43 for the two cropping seasons. Five accessions (NG/SA/DEC/07/0300, TOG-5453, TOG-6804, FARO-22, and FARO-57) were highly resistant, 10 were resistant, 14 moderately resistant, and 16 were moderately susceptible to the disease. In the 2017 cropping season, the result of the grain yield showed that accession Local Foreign and FARO 26 had the value of 46.77 g apiece while NG/SA/DEC/07/0278 had the least (11.00 g). However, in the 2019 cropping season, the results of the grain yield showed that accession Local Foreign produced the highest yield (56.00 g), FARO 26 had 40.31 g grain yield while NG/SA/DEC/07/0285 (22.0 g) had the lowest grain yield. The study concluded that using the blast-resistant cultivars is the best option in managing blast disease, and the five highly resistant accessions could be planted out in other agroecological zones for further studies on managing rice blast disease in the field.

Keywords: Screening; rice; blast; disease; field

INTRODUCTION

Rice (*Oryza sativa*, L.) is a member of the Poaceae family, and there are two domesticated species in the genus Oryza. *Oryza sativa* is indigenous to tropical and subtropical Southern Asia, whereas *Oryza glaberrima* is indigenous to West Africa (Habib et al., 2012; Shah et al., 2014). It is recognised as an important strategic food security crop and a critical component of Sub-Saharan African staple food economies (Salih et al., 2013). It is also Africa's fastest-growing food crop, with significant implications for food security and self-sufficiency in an increasing number of low-income food-deficient countries (FAO, 2012). Rice provides the majority of calories and a variety of nutrients such as iron, zinc, ß-carotene, fibre, vitamins, and minerals, and is low in cholesterol and sodium, implying that it is a healthy source of energy (Dipti et al., 2012; Khush, 2005; Sellamuthu et al., 2011). Africa, especially Nigeria, is abundantly blessed with land and water resources to support a huge expansion in rice production (Balasubramanian et al., 2007). Rice grows across all agroecological zones (AEZ) in Nigeria (African Rice, 2013). Rice can be grown in a variety of environments, including but not limited to drylands, rain-fed wetlands, deep water and mangrove swamps, and irrigated wetlands (Balasubramanian et al., 2007, Seck et al., 2012). Upland, hydromorphic, rain-fed lowland, irrigated lowland, deep inland water, and mangrove swamps are the six rice-growing environments (RGEs) identified by Chidiebere-Mark et al. (2019) in Nigeria. Farmers in Nigeria use a specific rice production system based on topography, input, and expected output area (FMARD, 2012). In Africa, 14.2 million ha and 17.1 million ha of land were cultivated, with 33.2 million tons and 38.5 million tons harvested in 2018 and 2019, respectively, with a similar productivity of 2.3 tons per hectare. Nigeria, for example, produced rice on 3.3 million hectares and 5.3 million ha of land, harvesting 6.8 million tons and 8.4 million tons, respectively, with a productivity of 2.03 tons/ha and 1.6 tons/ha (FAO, 2018; 2019). However, annual rice production only meets 62% of actual needs, despite demand rising faster than for any other staple food (Seck et al., 2013). Many factors contribute to low yield, but the most significant are infectious diseases such as rice blast (*Magnaporthe oryzae,* Cav.), brown leaf spot (*Bipolaris oryzae*), stem rot (*Sclerotium oryzae,* Catt.), and root rot disease (*Fusarium moniliforme*) (Fakir et al., 2002). Blast disease is a biotic stress in rice crops caused by a filamentous, ascomycetous fungus, *Magnaporthe oryzae*, Cav. It is an infectious fungal disease that is one of the most serious diseases affecting rice plants in every rice-cultivating field (WARDA, 2004; Neupane and Bhusal, 2021). It is widely distributed and prevalent in more than 85 countries worldwide (Jamal et al., 2012; Wang et al., 2014). Blast is one of the most serious threats to tropical rice production with yield losses of up to 80% on the field (Magar et al., 2015). Chemical control, while effective, raises cultivation costs and pollutes the environment, and utilising resistant varieties is the most cost-effective and effective strategy to control it, especially in resource-constrained farmer fields (Nalley et al., 2016). The resistance of genotypes varies by region, depending on the fungal strain predominant in the area (Raboin et al., 2016; Bano et al., 2017). Hence there is a need to screen forty-five lowland rice accessions for resistance to rice blast in the derived savannah agroecological zone of Nigeria. The hypotheses of this study stated in null hypothesis (H_{01}) form that there is no significant difference between the forty-five lowland rice accessions screened for resistance to blast disease under natural conditions. The null hypothesis (H_{02}) also stated that there is no significant difference in the yield performance of the forty-five rice accessions.

MATERIALS AND METHODS

Experimental site

Field experiments were conducted at the Teaching and Research Farm, Federal College of Agriculture, Ishiagu (Latitude 5°56′N and Longitude 7°41′E) South Eastern, Nigeria on clay-sandy soil during the 2017 and 2019 cropping seasons. The site is located in the derived savannah agroecological zone of Nigeria. Weather data during growth periods of experimentation in 2017 and 2019 are presented in Figure 1. The highest amount of rainfall was recorded in September 2017 and 2019 with values of 302.1 and 589.8 mm whereas the least was recorded in November with values of 0.00 and 316 mm, respectively. Rainfall recorded in September coinciding with the vegetative-reproductive period of rice was higher in both cropping seasons. The total amount of rainfall was higher in 2019 than 2017 cropping season. This underscored mildly cooler temperatures in 2019 (29–32 °C) than in 2017 (30–34 °C) during these periods. Values recorded for relative humidity during the two cropping seasons ranged between 81 and 87%. The location has a history of incidence of blast disease and it could be among the blast screening locations in Nigeria.

Sources of the rice seed

The forty-five rice seeds were sourced from three locations namely; National Centre for Genetic Resources and Biotechnology (NACGRAB), Moor Plantation, Ibadan, Oyo State, National Cereal Research Institute (NCRI), Badeggi, Minna, Niger State and Local farmers within Ishiagu, Ebonyi State.

Pre-germination of seeds and nursery preparation

The seeds were soaked in water for 24 hours and incubated for 48 hours in the laboratory to enhance uniform germination and early field establishment

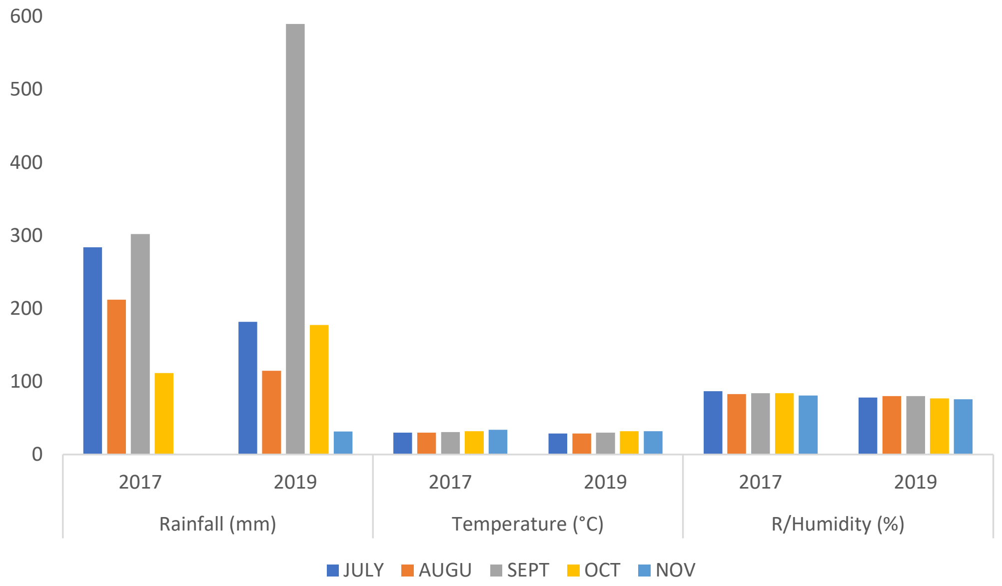

Figure 1. Weather variables for the 2017 and 2019 cropping seasons in Ishiagu, Ebonyi State

Table 1. Disease Severity rating scale

Scale	Reaction	IRRI Scale Equivalent	Host Response
0	No symptoms	No symptoms	Highly Resistant (HR)
1	1–5% of the leaves or panicles with lesions covering completely around the node	1–5% leaves area affected	Resistant (R)
2	6–25% of the leaves or panicles with lesions covering completely around the node	6–15% leaves area affected	Moderately Resistant (MR)
3	26–50% of the leaves or panicles with lesions covering completely around the node	16–50% of the leaves area affected	Moderately Susceptible (MS)
4	>50% of the leaves or panicles with lesions covering completely around the node	51–100% of the leaves area affected	Susceptible(S)

Source: IRRI (2002); Manandhar et al. (2016)

(Mohanta et al., 2003). Rice seedlings were each raised in a perforated plastic bucket. Five kilograms of the sandy loamy soil were put in each perforated bucket with five holes at the base. Each of the pre-germinated rice seeds was sown in a separate bucket, covered slightly with the topsoil to prevent rodent and birds' attacks, then watered lightly every day and observed for 3 weeks before transplanting.

Field layout and experimental design

Forty-five rice accessions were investigated for infection by the blast fungus during the 2017 and 2019 cropping seasons. The land was manually prepared; application of systemic herbicide on the weeds, clearing with a cutlass after three weeks, and stumping was done using a hoe. Row planting of 2 metres by length with an alley row of 1 m. The total land area for the experiment was 360 m^2. In a Randomised Complete Block Design (RCBD), each of the forty-five lowland rice accessions was replicated three (3) times. The extra seed placed in front of each accession filled in the gaps left by missing stands. Plants 1, 2, 3, 4, and 5 (P1, P2, P3, P4, and P5) were tagged in the centre of each accession and used for data collection during the trial. Weeding began three weeks and was repeated six and nine weeks after transplanting (Idowu et al., 2013).

Disease assessment

At physiological maturity (12 weeks after transplanting), the blast symptoms were scored using the Manandhar et al. (2016) method (Table 1). Percentage Disease Incidence (DI) is calculated using the formulae of Jamal et al. (2011).

$$\text{DI}\,(\%) = \frac{\text{Number of diseased plants}}{\text{Total number of plants per plot}} \times 100$$

Disease Severity (DS) is calculated using the formula adopted from Gwary et al. (2009).

$$\text{Disease severity} = \frac{\Sigma n \times 100}{N \times S}$$

where, Σ = summation, n = number of infected leaves, N = Number of leaves assessed and S = Maximum numerical grade,

Agronomic data

The following agronomic data were collected on plant height (cm), number of tillers, leaf area (cm^2), 100-grain weight (g), and grain yields per plant (g) from five tagged plants in each plot at physiological maturity (12 WAT) per International Rice Research Institute (IRRI, 2002) procedures.

Statistical analysis of data

Data collected on rice disease intensity and agronomic performance were subjected to Analysis of Variance (ANOVA) using Minitab software version 17 and the significant means were separated using the Tukey test at $p < 0.05$.

RESULTS

Percentage disease incidence of the forty-five lowland rice accessions screened for resistance to rice blast disease during the 2017 and 2019 cropping seasons in Ishiagu, Ebonyi State

Table 2 shows the percentage disease incidence of the forty-five lowland rice accessions screened for resistance to rice leaf blast disease during the 2017 and 2019 cropping seasons. The results showed a significant ($p \leq 0.05$) difference among the forty-five lowland rice accessions screened for rice leaf blast disease during the 2017 cropping season. The accessions NG/SA/JAN/023 (66.95%) had the highest disease incidence, followed by FARO-19 (48.11%) while NG/SA/DEC/07/0302, NG/SA/DEC/07/0300, NG/OA/10/11/055, NG/SA/JAN/09/016, TOG 5453, TOG 6804, FARO-17, FARO-22, FARO-26, FARO-27, FARO-30, FARO-52, and FARO-57 had no blast disease symptoms. In the 2019 cropping season, the results showed a significant ($p \leq 0.05$) difference among the forty-five lowland rice accessions screened for rice blast disease. The accession NG/SA/JAN/023 (51.17%) had the highest disease incidence, followed by NERICA 1 (46.42%) while the accessions NG/SA/DEC/07/0300, NG/SA/DEC/07/0286, TOG 5453, TOG 6804, FARO-22 and FARO-57 had no blast disease symptoms. On the pooled mean, the accession NG/SA/JAN/023 (59.06%) had the highest disease incidence, followed by NERICA 1 (43.67%) while accessions NG/SA/DEC/07/0300, TOG 5453, TOG 6804, FARO-22 and FARO-57 had no blast symptoms for the two cropping seasons.

The severity of rice leaf blast disease in forty-five lowland rice accessions screened for resistance during the 2017 and 2019 cropping seasons in Ishiagu, Ebonyi State

Table 2 shows the disease severity of the forty-five lowland rice accessions screened for resistance to rice leaf blast disease during the 2017 and 2019 cropping seasons. The results show a significant ($p \leq 0.05$) difference among the forty-five lowland rice accessions screened for rice leaf blast disease during the 2017 cropping season. The accessions NG/SA/DEC/07/0278 (3.42) had the highest disease severity, followed by FARO 19 (3.22) while NG/SA/DEC/07/0302, NG/SA/DEC/07/0300, NG/OA/10/11/055, NG/SA/JAN/09/016, TOG 5453, TOG 6804, FARO 17, FARO 22, FARO 26, FARO 27, FARO 30, FARO 52 and FARO 57 had no leaf blast disease symptoms. In the 2019 cropping season, the results also showed a significant ($p \leq 0.05$) difference among the forty-five lowland rice accessions screened for rice leaf blast. The accession FARO 19 and FARO 21 had the highest disease severity with 3.22 apiece; followed by NG/SA/JAN/09/026 (3.13) while the accessions NG/SA/DEC/07/0300, NG/SA/DEC/07/0286, TOG 5453, TOG 6804, FARO 22 and FARO 57 had no leaf blast disease symptoms. On the pooled mean, the accession NG/SA/DEC/07/0278 (3.43) had the highest disease incidence, followed by FARO 19 (3.25) while accessions NG/SA/DEC/07/0300, TOG 5453, TOG 6804, FARO 22 and FARO 57 had no leaf blast symptoms for the two cropping seasons.

Determination of the resistance levels of forty-five lowland rice accessions screened for resistance to rice blast disease during the 2017 and 2019 cropping seasons in Ishiagu, Ebonyi State

The results show that resistance levels of forty-five rice accessions on rice leaf blast disease varied significantly. In the 2017 cropping season, thirteen rice accessions (NG/SA/DEC/07/0302, NG/OA/10/11/055, NG/SA/DEC/07/0300, NG/SA/JAN/09/016, TOG 5453, TOG 6804, FARO 30, FARO 22, FARO 26, FARO 17, FARO 52, FARO 27 and FARO 57) were highly resistant. Three accessions (NERICA L-34, NG/SA/DEC/07/0286 and FARO 60) were resistant, ten (FARO 43, LOCAL FOREIGN, NG/SA/DEC/07/0294, NG/SA/DEC/07/0280, NG/SA/DEC/07/0295, NG/SA/DEC/07/0287, FARO 51, FARO 61, FARO 33 and FARO 44) were moderately resistant while nineteen (NG/SA/DEC/07/0289, NG/SA/DEC/07/0292, NG/SA/DEC/07/0278, NG/SA/DEC/07/0285, NERICA 1, NERICA 7, NG/SA/JAN/023, NG/SA/JAN/09/021, NERICA 2,

NG/SA/JAN/09/022, NG/SA/DEC/07/0293, NG/SA/JAN/09/025, NG/SA/DEC/07/0291, NG/SA/JAN/09/026, NG/SA/DEC/07/0283, FARO 16, FARO 19, FARO 21 and FARO 32) were moderately susceptible and none was susceptible to the pathogen (Table 3). In the 2019 cropping season, seven rice accessions (NG/SA/DEC/07/0300, NG/SA/DEC/07/0286, TOG 5453, TOG 6804, FARO 22, FARO 26 and FARO 57) were highly resistant, eight (NG/SA/DEC/07/0302, NG/OA/10/11/055, NG/SA/JAN/09/016, NERICA L-34, FARO 60, FARO 30, FARO 52 and FARO 27) were resistant, and thirteen (FARO 43, LOCAL FOREIGN, NG/SA/DEC/07/0294, NG/SA/DEC/07/0280, NG/SA/DEC/07/0295, NG/SA/DEC/07/0287, NG/SA/DEC/07/0292, NERICA 1, FARO 32, FARO 17, FARO 51, FARO 61 and FARO 33) were moderately resistant, seventeen (NG/SA/DEC/07/0289, NG/SA/DEC/07/0278, NG/SA/DEC/07/0285, NERICA 7, NG/SA/JAN/023, NG/SA/JAN/09/021, NERICA 2, NG/SA/JAN/09/022, NG/SA/DEC/07/0293, NG/SA/JAN/09/025, NG/SA/DEC/07/0291, NG/SA/JAN/09/026, NG/SA/DEC/07/0283, FARO 16, FARO 19, FARO 21 and FARO 44) were moderately susceptible while none of the rice accessions screened was susceptible. However, the results of the pooled means showed a significant ($p \leq 0.05$) difference among the forty-five rice accessions. Five accessions were highly resistant (NG/SA/DEC/07/0300, TOG 5453, TOG 6804, FARO 22 and FARO 57). Ten accessions (NG/SA/DEC/07/0302, NERICA L-34, NG/SA/DEC/07/0286, NG/OA/10/11/055, FARO 60, FARO 30, FARO 17, FARO 27, FARO 52 and FARO 26) were resistant. Fourteen accessions (FARO 43, LOCAL FOREIGN, NG/SA/JAN/09/016, NG/SA/DEC/07/0294, NG/SA/DEC/07/0280, NG/SA/DEC/07/0295, NG/SA/DEC/07/0287, NG/SA/DEC/07/0289, NERICA 1, FARO 32, FARO 51, FARO 61, FARO 33 and FARO 44) were moderately resistant while sixteen accessions (NG/SA/DEC/07/0292, NG/SA/DEC/07/0278, NG/SA/DEC/07/0285, NERICA 7, NG/SA/JAN/023, NG/SA/JAN/09/021, NERICA 2, NG/SA/JAN/09/022, NG/SA/DEC/07/0293, NG/SA/JAN/09/025, NG/SA/DEC/07/0291, NG/SA/JAN/09/026, NG/SA/DEC/07/0283, FARO 16, FARO 19 and FARO 21 were found to be moderately susceptible and none of the accessions screened was susceptible to the blast disease (Table 3).

Agronomic performance of the forty-five lowland rice accessions screened for resistance to rice blast disease during the 2017 cropping season in Ishiagu, Ebonyi State

Table 4 shows the agronomic performance of the forty-five lowland rice accessions screened for resistance to rice blast disease during the 2017 cropping season in Ishiagu. The results of the plant height, number of tillers per plant, leaf area, 100-grain weight, and weight of the grains yield during the 2017 cropping season show a significant ($p \leq 0.05$) difference among the forty-five lowland rice accessions under study. The accession FARO 27 (131.50 cm) had the highest plant height followed by NG/SA/DEC/07/0278 (124.43 cm) while the accession FARO 51 (51.53 cm) had the least. The result of the number of tillers per plant revealed that accession LOCAL FOREIGN (20.89) had the highest number of tillers, followed by accession NG/SA/DEC/07/0295 (20.20) while the accession NERICA 1 (3.32) had the least. The result of the leaf area revealed that FARO 61 (1163.54 cm^2) had the highest, followed by accession LOCAL FOREIGN (906.39 cm^2) while NERICA 1accession (115.20 cm^2) had the least. The 100-grain weight showed that accession NG/SA/DEC/07/0283 (4.21 g) had the highest weight followed by NG/SA/JAN/023 (4.12 g) while NG/SA/DEC/07/0302 (1.46 g) had the least. However, the result of the grain yield showed that accession local foreign and FARO 26 had the value of 46.77 g apiece, followed by the accessions FARO 57 (42.90 g) while NG/SA/DEC/07/0278 (11.00 g) had the least.

Agronomic performance of the forty-five lowland rice accessions screened for resistance to rice blast disease during the 2019 cropping season in Ishiagu, Ebonyi State

Table 5 shows the agronomic performance of the forty-five lowland rice accessions screened for resistance to rice blast disease during the 2019 cropping season in Ishiagu. The results of the plant height, number of tillers per plant, leaf area, 100-grain weight, and weight of the grains yield during the 2019 cropping season show a significant ($p \leq 0.05$) difference among the forty-five lowland rice accessions investigated. The accession FARO 27 (128.34 cm) had the highest plant height followed by the accessions NG/SA/DEC/07/0278, NG/SA/JAN/09/022, and NG/SA/DEC/07/0294 with the values of 119.55 cm, 118.78 cm and 118.75 cm, respectively, while the accession FARO-51 (49.78 cm) had the least. The result of the number of tillers per plant revealed that accession NG/SA/DEC/07/0295 (19.20) had the highest number of tillers, followed by accession LOCAL FOREIGN (18.13) while accession NERICA-1 (4.67) had the least. The result of the leaf area revealed that NG/SA/DEC/07/0295 (692.39 cm^2) had the highest, followed by accession LOCAL FOREIGN (687.73cm^2) while NERICA-1 accession (172.19 cm^2) had the least. The 100-grain weight showed that accession NG/SA/DEC/07/0283 (4.19 g) was the highest followed by NG/SA/DEC/07/0278 (3.95 g) while NG/SA/DEC/07/0302 (1.47 g) was the lowest. However, the result of the grain yield showed that accession local foreign (56.00 g) had the highest; followed by FARO-16 (49.10 g) while NG/SA/DEC/07/0285 (22.0 g) had the least.

Hypothesis testing

(H_0): There is no significant difference between the resistance levels and yield performance of forty-five lowland rice accessions screened under natural conditions.

The results in Table 3 show a significant difference ($p \leq 0.05$) among the forty-five lowland rice accessions screened for resistance to blast disease during the 2017 and 2019 cropping seasons. The pooled means revealed that five accessions were highly resistant, ten were resistant, and fourteen were moderately resistant whereas sixteen accessions were found to be moderately susceptible and none of the accessions screened was susceptible to the blast disease. The result in Table 4 showed a significant difference ($p \leq 0.05$) in the yield attributes of forty-five lowland accessions during the 2017 cropping season with accession Local Foreign and FARO 26 having a value of 46.77 g apiece while NG/SA/DEC/07/0278 had the least (11.00 g). Table 5 results also revealed a significant difference ($p \leq 0.05$) in yield performance during the 2019 cropping season with accession Local Foreign producing the highest yield (56.00 g), FARO 26 had 40.31 g grain yield while NG/SA/DEC/07/0285 (22.0 g) had the lowest grain yield. The differences in their reactions to blast pathogen infection and yield attributes indicate a significant difference among the forty-five accessions.

DISCUSSION

The observed symptoms comprised dead tissues and were more typically found on the leaves. The blast lesions may lower the plant leaf area, affecting the rice plant's photosynthetic activity and causing lower absorption in the visible region. This is similar to the findings of Zhang et al. (2020). Kobayashi et al. (2016) stated that brown lesions on the leaves may be attributed to decreased contents of chlorophyll pigments in response to *M. oryzae* infection, which caused the pigments to deteriorate. The variations in disease incidence and severity may be due to the nature of the genotype and inoculum load in the prevailing environment and their interactions. Hossain and Srikant (2001) reported variability in rice germplasm in response to various diseases. Similarly, Izge et al. (2007) stated that variability exists among different varieties of all characters due to their inherent resistance to attack by pathogens. Furthermore, five accessions were highly resistant, ten were resistant, fourteen were moderately resistant, sixteen were moderately susceptible, and none were susceptible (S) to rice blast disease. This study revealed that accessions NG/SA/DEC/07/0300, TOG 5453, TOG 6804, FARO-22, and FARO-57 maintained their immunity to blast pathogens consistently for the two cropping seasons. The resistance ability of these accessions may be genetics as it suppresses the organism's development causing the blast disease. Similar results were reported by Haq et al. (2002) who tested twenty-five rice lines and discovered that KSK-282 and IRRI-6 were extremely resistant. Khati et al. (2007) screened 78 soybean germplasms, identifying 16 resistant genotypes, 23 moderately resistant genotypes with spots on only a few plants, thirty moderately susceptible genotypes, and nine susceptible genotypes. Ghazanfar et al. (2009) and Mahendra et al. (2022) stated that among the rice genotypes screened, 6 genotypes were found resistant, three were moderately resistant and one was highly susceptible to rice blast. Local foreign screened for blast lesions were moderately resistant but produced higher grain yield compared to their highly resistant or immune counterparts. This suggests that the accession is tolerant to the blast disease. Going by the reasoning of Pagán and García-Arenal (2018) who defined crop tolerance as the quality that enables a susceptible organism to endure severe pathogen attack without sustaining losses in yield. Ney et al. (2013) also stated that tolerance to a pathogen is usually defined as the host’s ability to alleviate the reduction in its fitness due to infection without reducing the growth of the pathogen. Using the rating scale with the inclusion of yield in the assessment of the rice accession for resistance to leaf blast, the local foreign was tolerant to *M. oryzae* pathogen. This finding justifies the report of Mikaberidze and McDonald (2020) who investigated the tolerance level in 335 elite wheat cultivars to the fungal pathogen *Zymoseptoria tritici*. The reaction of these accessions to blast fungus demonstrates the validity of the suggestion that economic yield should be universally used as a true measure of crop damage in rating crops for resistance, tolerance, susceptibility, and hypersusceptibility to blast pathogens.

Table 2. Percentage of disease incidence and severity of forty-five rice accessions screened under natural infection during 2017 and 2019 cropping seasons

Accessions	Disease incidence (%)			Disease Severity		
	2017	2019	Pooled means	2017	2019	Pooled means
FARO 43	36.94b-f	38.83a-d	37.89b-f	1.56d-f	1.80a-f	1.68d-g
LOCAL FOREIGN	27.95d-k	29.22c-i	28.59d-l	1.99b-f	2.10a-f	2.05b-f
NG/SA/DEC/07/0302	0.00n	5.44lm	2.72rs	0.00g	0.70e-g	0.35hi
NG/SA/DEC/07/0294	28.61d-j	29.89b-h	29.25d-k	1.99b-f	2.13a-f	2.06b-f
NG/SA/DEC/07/0280	31.21c-i	33.60b-g	32.41b-j	2.16a-f	2.17a-f	2.16a-e
NG/SA/DEC/07/0289	36.96b-f	38.39a-e	37.68b-g	2.49a-e	2.57a-c	2.53a-e
NG/SA/DEC/07/0295	14.43k-m	18.90g-l	16.67l-q	2.15a-f	2.27a-e	2.21a-e
NG/SA/DEC/07/0287	36.33b-g	39.22a-d	37.78b-g	2.08b-f	2.03a-f	2.06b-f
NG/SA/DEC/07/0292	36.95b-f	40.32a-d	38.63b-e	2.52a-e	2.43a-c	2.48a-e
NG/SA/DEC/07/0278	45.15bc	27.59c-j	36.37b-h	3.42a	3.07a-c	3.43a
NG/SA/DEC/07/0285	29.33d-j	26.63d-j	27.98e-l	2.52a-e	2.50a-c	3.23ab
NG/SA/DEC/07/0300	0.00n	0.00m	0.00s	0.00g	0.00g	0.00i
NERICA 1	40.92bcd	46.42ab	43.67b	2.63a-d	1.97a-f	2.30a-e
NERICA L-34	22.25h-m	16.22h-m	19.24k-p	1.33ef	1.52c-g	1.43e-h
NERICA 7	33.00c-h	36.49a-f	34.75b-i	2.91a-c	2.97a-c	2.94a-d
NG/SA/JAN/023	66.95a	51.17a	59.06a	2.67a-d	2.80a-c	2.73a-d
NG/OA/10/11/055	0.00n	5.43lm	2.72rs	0.00g	0.67fg	0.33hi
NG/SA/JAN/09/021	36.68b-f	33.05b-g	34.87b-i	2.50a-e	2.53a-c	2.57a-e
NERICA 2	27.82d-k	31.42b-h	29.62d-k	2.53a-e	2.63a-c	2.58a-e
NG/SA/JAN/09/022	22.52g-m	25.91d-j	24.21h-n	2.67a-d	2.63a-c	2.65a-e
NG/SA/DEC/07/0293	27.63d-k	32.63b-h	30.13c-k	2.48a-e	2.53a-c	2.51a-e
NG/SA/JAN/09/025	38.38b-e	43.69abc	41.03bcd	2.81a-d	2.80a-c	2.81a-d
NG/SA/JAN/09/016	0.00n	7.24klm	3.62rs	0.00g	0.67fg	0.33hi
NG/SA/DEC/07/0291	27.48d-l	30.60b-h	29.04d-l	2.55a-e	2.66a-c	2.61a-e
NG/SA/JAN/09/026	24.96e-l	22.04e-k	23.50i-n	3.00a-c	3.13ab	3.07abc
NG/SA/DEC/07/0283	22.44g-m	28.10c-j	25.27g-m	2.53a-e	2.67a-c	2.60a-e
NG/SA/DEC/07/0286	13.52l-n	0.00m	6.76p-s	1.06fg	0.00g	0.53ghi
TOG 5453	0.00n	0.00m	0.00s	0.00g	0.00g	0.00i
TOG 6804	0.00n	0.00m	0.00s	0.00g	0.00g	0.00i
FARO 16	18.02i-m	12.25j-m	15.14m-r	2.48a-e	2.50a-c	2.49a-e
FARO 60	9.47mn	11.98j-m	10.73o-s	0.94fg	0.80d-g	0.87f-i
FARO 19	48.11b	36.98a-f	42.55bc	3.22ab	3.27a	3.25ab
FARO 21	44.37bc	30.39b-h	37.38b-g	3.11a-c	3.27a	3.19ab
FARO 30	0.00n	8.51k-m	4.26qrs	0.00g	0.77d-g	0.38hi
FARO 32	16.56j-m	7.91k-m	12.23n-s	2.48a-e	1.60b-f	2.04b-f
FARO 22	0.00n	0.00m	0.00s	0.00g	0.00g	0.00i
FARO 26	0.00n	12.87i-m	6.43qrs	0.00g	0.83d-g	0.47ghi
FARO 17	0.00n	6.67klm	3.33rs	0.00g	0.67fg	0.33hi
FARO 51	18.72i-m	21.41f-l	20.07j-o	1.89c-f	1.90a-f	1.90c-f
FARO 52	0.00n	7.28klm	3.64rs	0.00g	0.700e-g	0.35hi
FARO 61	17.11j-m	21.62f-l	19.37k-o	1.97b-f	1.63b-f	1.80c-f
FARO 27	0.00n	8.67k-m	4.33qrs	0.00g	0.83d-g	0.42ghi
FARO 57	0.00n	0.00m	0.00s	0.00g	0.00g	0.00i
FARO 33	22.94f-m	28.40c-j	25.67f-m	1.96b-f	2.33a-d	2.15b-e
FARO 44	27.92d-k	31.74b-h	29.83d-k	2.12b-f	2.60a-c	2.36a-e
MEANS	21.15	21.89	21.52	1.660	1.7699	1.7351
SE	1.47	1.30	1.35	0.104	0.0955	0.0991
CV(%)	**80.94**	**69.24**	**72.79**	**72.77**	**62.67**	**66.35**

Means in the same column with different superscripts are significantly different ($p < 0.05$) using Tukey. SE means Standard Error while CV means Coefficient of Variation

Table 3. Determination of the resistant levels of forty-five lowland rice accessions screened for resistance to rice blast disease during the 2017 and 2019 cropping seasons in Ishiagu, Ebonyi State

	Resistant levels					
Accessions	**2017**		**2019**		**Pooled mean**	**Status**
FARO 43	13.33ijk	MR	19.37e-h	MR	16.35ijk	MR
LOCAL FOREIGN	21.21f-i	MR	21.83d-h	MR	21.52f-j	MR
NG/SA/DEC/07/0302	0.00m	HR	2.17jk	R	1.08mn	R
NG/SA/DEC/07/0294	18.72h-k	MR	20.03e-h	MR	19.38g-k	MR
NG/SA/DEC/07/0280	19.58g-j	MR	20.87d-h	MR	20.22g-k	MR
NG/SA/DEC/07/0289	16.70ijk	MR	18.37fgh	MR	17.53h-k	MR
NG/SA/DEC/07/0295	12.33jk	MR	14.67hij	MR	13.50jk	MR
NG/SA/DEC/07/0287	14.58ijk	MR	16.63ghi	MR	15.61ijk	MR
NG/SA/DEC/07/0292	30.10cde	MS	32.37a-e	MS	31.23b-f	MS
NG/SA/DEC/07/0278	35.91a-d	MS	40.90abc	MS	38.41abc	MS
NG/SA/DEC/07/0285	27.85d-g	MS	30.33b-f	MS	29.09c-g	MS
NG/SA/DEC/07/0300	0.00m	HR	0.00k	HR	0.00n	HR
NERICA 1	26.27e-h	MS	28.17c-g	MR	27.22d-h	MS
NERICA L-34	3.10lm	R	3.57ijk	R	3.33lmn	R
NERICA 7	35.90a-d	MS	39.37abc	MS	37.63abc	MS
NG/SA/JAN/023	29.67cde	MS	32.23a-e	MS	30.95b-f	MS
NG/OA/10/11/055	0.00m	HR	1.77jk	R	0.88n	R
NG/SA/JAN/09/021	31.47b-e	MS	35.37abc	MS	33.42b-e	MS
NERICA 2	32.77b-e	MS	39.13abc	MS	35.95a-d	MS
NG/SA/JAN/09/022	33.93b-e	MS	35.50abc	MS	34.71a-d	MS
NG/SA/DEC/07/0293	35.80a-d	MS	37.27abc	MS	36.53a-d	MS
NG/SA/JAN/09/025	38.97ab	MS	41.80ab	MS	40.38ab	MS
NG/SA/JAN/09/016	0.00m	HR	1.70jk	R	0.85n	MR
NG/SA/DEC/07/0291	37.50abc	MS	39.20abc	MS	38.35abc	MS
NG/SA/JAN/09/026	32.80b-e	MS	33.83a-d	MS	33.32b-e	MS
NG/SA/DEC/07/0283	30.37cde	MS	31.97a-e	MS	31.17b-f	MS
NG/SA/DEC/07/0286	2.73lm	R	0.00k	HR	1.37mn	R
TOG 5453	0.00m	HR	0.00k	HR	0.00n	HR
TOG 6804	0.00m	HR	0.00k	HR	0.00n	HR
FARO 16	29.37c-f	MS	29.37b-g	MS	29.37c-g	MS
FARO 60	2.53lm	R	2.23jk	R	2.38lmn	R
FARO 19	29.67cde	MS	30.97b-f	MS	30.29c-f	MS
FARO 21	42.50a	MS	44.57a	MS	43.53a	MS
FARO 30	0.00m	HR	2.03jk	R	1.02mn	R
FARO 32	28.30def	MS	20.23e-h	MR	24.27e-i	MR
FARO 22	0.00m	HR	0.00k	HR	0.00n	HR
FARO 26	0.00m	HR	1.77jk	HR	0.88n	R
FARO 17	0.00m	HR	1.33jk	MR	0.67n	R
FARO 51	12.22jk	MR	10.83h-k	MR	11.53jkl	MR
FARO 52	0.00m	HR	1.80jk	R	0.90n	R
FARO 61	10.52kl	MR	11.53h-k	MR	11.03klm	MR
FARO 27	0.00m	HR	1.80jk	R	0.90n	R
FARO 57	0.00m	HR	0.00k	HR	0.00n	HR
FARO 33	18.17h-k	MR	18.47fgh	MR	18.32h-k	MR
FARO 44	17.93h-k	MR	19.77e-h	MS	18.85h-k	MR
MEANS	17.17		18.56		17.86	
SE	1.25		1.33		1.28	
CV(%)	84.71		83.22		83.47	

Means in the same column with different superscripts are significantly different ($p < 0.05$) using Tukey. SE means Standard Error while CV means Coefficient of Variation. Note: HR = Highly Resistant, R = Resistant, MR = Moderately Resistant, MS = Moderately Susceptible

Table 4. Agronomic performance of the forty-five lowland rice accessions screened for resistance to rice blast disease during the 2017 cropping season in Ishiagu, Ebonyi State

Accessions	Plant height at maturity (cm)	Number of tiller/ plant	Leaf area (cm^2)	100 Grain weight (g)	Grain yields per plant (g)
FARO 43	98.00ij	16.77a-f	488.02f-n	2.58t	39.30a-d
LOCAL FOREIGN	102.13hi	20.89a	906.39ab	4.10a-c	46.77a
NG/SA/DEC/07/0302	77.43pqr	14.10c-j	542.79e-l	1.46v	18.01e-k
NG/SA/DEC/07/0294	120.93bc	10.80g-p	390.21g-q	3.86a-e	16.45g-k
NG/SA/DEC/07/0280	114.90de	17.17a-e	726.42b-f	3.23h-p	34.80a-h
NG/SA/DEC/07/0289	85.87mn	13.77c-k	596.67d-j	2.82o-t	16.18g-k
NG/SA/DEC/07/0295	102.40ghi	20.20ab	774.97b-e	2.77q-t	17.37f-k
NG/SA/DEC/07/0287	93.50jkl	11.56e-n	501.60f-n	3.09k-r	22.13c-k
NG/SA/DEC/07/0292	107.30fg	11.34e-n	355.69i-r	3.05l-s	12.11jk
NG/SA/DEC/07/0278	124.43b	18.53a-c	880.41bc	4.10a-c	11.00k
NG/SA/DEC/07/0285	114.23de	15.00b-h	628.21c-h	3.06l-s	16.75g-k
NG/SA/DEC/07/0300	114.17de	6.43n-r	250.03m-r	2.10u	20.55d-k
NERICA 1	122.00bc	3.32r	115.20r	3.95a-d	28.46a-k
NERICA L-34	83.87mno	6.44n-r	256.89m-r	2.89n-t	27.31a-k
NERICA 7	112.00ef	3.89qr	153.61qr	3.73b-f	39.09a-d
NG/SA/JAN/023	118.57cd	6.44n-r	285.13l-r	4.12ab	22.06c-k
NG/OA/10/11/055	83.63no	5.48o-r	210.90o-r	3.27g-n	18.48e-k
NG/SA/JAN/09/021	101.10hi	5.44p-r	203.79p-r	3.67b-g	38.97a-d
NERICA 2	79.43opq	3.78qr	151.49qr	3.94a-d	28.30a-k
NG/SA/JAN/09/022	122.00bc	7.18m-r	252.04m-r	3.77a-f	23.61b-k
NG/SA/DEC/07/0293	84.90mn	9.23h-q	390.67g-q	3.27g-n	14.15ijk
NG/SA/JAN/09/025	75.73qrs	9.85g-p	343.44i-r	3.93a-d	33.50a-i
NG/SA/JAN/09/016	72.73rst	7.89l-r	337.90j-r	2.78q-t	12.03jk
NG/SA/DEC/07/0291	88.93lm	11.32e-o	481.99f-n	2.95m-t	16.21g-k
NG/SA/JAN/09/026	68.33tu	12.29d-n	472.49f-o	3.45e-l	37.12a-f
NG/SA/DEC/07/0283	60.77r	15.56a-g	574.37d-k	4.21a	18.06e-k
NG/SA/DEC/07/0286	94.90jk	10.47g-p	323.27k-r	3.07l-s	19.60d-k
TOG 5453	117.47cd	10.45g-p	628.95c-h	3.57d-j	14.57h-k
TOG 6804	65.53ur	12.56d-m	824.88b-d	3.85a-e	16.08g-k
FARO 16	53.87w	11.11f-p	359.67i-r	3.82a-e	39.33a-d
FARO 60	75.33qrs	10.77g-p	476.26f-n	3.53d-k	30.89a-k
FARO 19	68.67tu	9.20h-q	348.24i-r	3.26g-o	31.58a-j
FARO 21	74.10rs	15.56a-g	731.95b-f	2.95m-t	41.49abc
FARO 30	72.00st	17.67a-d	644.25b-g	3.05l-s	31.61a-j
FARO 32	64.00ur	14.77b-h	571.31d-k	2.63st	25.59b-k
FARO 22	62.37r	8.67i-r	367.28h-r	2.65st	30.55a-k
FARO 26	85.27mn	12.33d-m	512.10f-m	2.93m-t	46.77a
FARO 17	81.87nop	14.23c-i	600.80d-i	3.66c-h	31.49a-j
FARO 51	51.53w	10.44g-p	433.13g-p	3.63d-i	29.91a-k
FARO 52	91.70kl	13.33c-l	540.97e-l	3.15j-r	41.25abc
FARO 61	52.27w	13.85c-k	1163.54a	3.19i-q	34.55a-h
FARO 27	131.50a	10.67g-p	389.18g-q	2.79p-t	33.11a-i
FARO 57	101.50hi	6.97m-r	286.34l-r	3.35f-m	42.90ab
FARO 33	104.00gh	8.10k-r	288.91l-r	3.36f-m	38.07a-e
FARO 44	97.53ij	8.28j-r	247.63n-r	2.75r-t	35.77a-g
MEANS	90.55	11.202	466.9	3.2748	27.641
SE	1.86	0.391	20.0	0.0496	0.983
CV(%)	23.85	40.59	49.80	17.59	41.34

Means in the same column with different superscripts are significantly different ($p < 0.05$) using Tukey. SE means Standard Error while CV means Coefficient of Variation

Table 5. Agronomic performance of the forty-five lowland rice accessions screened for resistance to rice blast disease during the 2019 cropping season in Ishiagu, Ebonyi State

Accessions	Plant height at maturity (cm)	Number of tiller/ plant	Leaf area (cm^2)	100 Grain weight (g)	Grain yields per plant (g)
FARO 43	91.75b-k	15.50a-e	424.90a-j	2.76no	39.03a-e
LOCAL FOREIGN	99.00a-h	18.13a-b	687.73a	3.88a-d	56.00a
NG/SA/DEC/07/0302	78.16f-m	13.33b-h	413.84a-j	1.47q	24.73de
NG/SA/DEC/07/0294	118.75ab	10.00g-o	329.67d-j	3.94a-c	21.45e
NG/SA/DEC/07/0280	77.44f-m	16.34a-d	653.37ab	3.11g-n	40.57a-e
NG/SA/DEC/07/0289	83.04e-l	13.13c-i	482.89a-g	2.82m-o	30.70b-e
NG/SA/DEC/07/0295	99.01a-h	19.20a	692.39a	2.77no	26.93de
NG/SA/DEC/07/0287	96.37b-j	11.67d-j	484.75a-g	3.03i-o	30.13b-e
NG/SA/DEC/07/0292	104.23a-g	10.33g-n	333.39d-j	2.95k-o	29.10c-e
NG/SA/DEC/07/0278	119.55ab	15.67a-e	595.61a-d	3.95ab	27.25de
NG/SA/DEC/07/0285	104.29a-g	13.43b-h	526.59a-f	2.98j-o	22.00e
NG/SA/DEC/07/0300	112.43a-e	6.67l-p	230.68g-j	2.03pq	31.37b-e
NERICA 1	116.24a-c	4.67p	172.19j	3.62a-i	32.13b-e
NERICA L-34	80.65f-l	6.77k-p	249.63f-j	2.90l-o	29.80b-e
NERICA 7	107.01a-f	5.37op	191.96h-j	3.33c-n	48.47abc
NG/SA/JAN/023	114.60a-d	7.57j-p	271.20f-j	3.73a-g	29.80b-e
NG/OA/10/11/055	78.30f-m	6.40l-p	222.76g-j	3.24e-n	29.33b-e
NG/SA/JAN/09/021	97.61b-i	5.77nop	196.05h-j	3.40b-m	40.77a-e
NERICA 2	82.29e-l	5.93m-p	184.66ij	3.81a-f	38.30a-e
NG/SA/JAN/09/022	118.78ab	6.53l-p	237.15g-j	3.62a-i	35.67b-e
NG/SA/DEC/07/0293	86.73c-k	8.97h-p	317.08d-j	3.18g-n	25.89de
NG/SA/JAN/09/025	76.58g-m	10.10g-o	336.96d-j	3.84a-e	35.90b-e
NG/SA/JAN/09/016	75.66g-m	8.50i-p	280.82e-j	2.73no	26.20de
NG/SA/DEC/07/0291	89.78b-k	12.03d-j	356.54d-j	3.15g-n	23.53de
NG/SA/JAN/09/026	69.34h-m	11.93d-j	413.76a-j	3.23e-n	42.50a-d
NG/SA/DEC/07/0283	62.16k-m	13.35b-h	420.94a-j	4.19a	27.23de
NG/SA/DEC/07/0286	91.03b-k	12.10d-j	373.8b-j	2.96j-o	23.87de
TOG 5453	111.34a-e	11.10e-l	447.43a-j	3.33c-n	31.60b-e
TOG 6804	68.67i-m	13.00c-i	640.11a-c	3.56b-k	33.09b-e
FARO 16	54.82l-m	11.10e-l	374.37b-j	3.65a-h	49.10ab
FARO 60	77.15f-m	10.65f-m	454.91a-i	3.57b-j	42.23a-d
FARO 19	67.23j-m	10.19g-n	400.71b-j	3.17g-n	32.07b-e
FARO 21	72.64h-m	14.77a-g	595.61a-d	3.00i-o	40.63a-e
FARO 30	69.86h-m	17.68abc	644.58a-c	2.96j-o	32.13b-e
FARO 32	62.02k-m	15.22a-f	554.74a-e	2.45op	23.58de
FARO 22	61.79k-m	11.67d-j	375.42b-j	2.44op	25.70de
FARO 26	85.48d-k	11.57d-k	423.25a-j	2.84l-o	40.31a-e
FARO 17	79.41f-m	12.83d-i	468.94a-h	3.30d-n	28.83cde
FARO 51	49.78m	9.73h-o	319.59d-j	3.44b-l	30.63b-e
FARO 52	87.52c-k	12.09d-j	407.65b-j	3.10h-n	40.95a-e
FARO 61	54.01l-m	12.80d-i	484.37a-g	3.30d-n	35.21b-e
FARO 27	128.34a	10.67f-m	340.34d-j	2.82m-o	31.47b-e
FARO 57	96.747b-j	7.63j-p	321.47d-j	3.23e-n	38.70a-e
FARO 33	95.813b-j	9.48h-o	405.42b-j	3.21f-n	40.03a-e
FARO 44	95.800b-j	9.61h-o	368.10c-j	2.44op	31.60b-e
MEANS	87.76	11.137	401.8	3.1651	33.256
SE	1.80	0.318	13.4	0.0466	0.781
CV (%)	23.78	33.22	38.85	17.11	27.29

Means in the same column with different superscripts are significantly different ($p < 0.05$) using Tukey. SE means Standard Error while CV means Coefficient of Variation

CONCLUSION

Assessment of the tested rice accessions for resistance to blast disease is important in the management of rice disease throughout the growing state in order to prioritize disease management strategy and increase the yield output of the farmers. The study showed that accessions NG/SA/DEC/07/0300, TOG 5453, TOG 6804, FARO-22, and FARO-57 were highly resistant to blast pathogens with low yield. However, Local Foreign were moderately resistant to the blast pathogen with higher grain yield. Therefore, based on our study, we recommend that local foreign candidates be disseminated to farmers.

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CONFLICT OF INTEREST

The authors declared no conflicts of interest concerning the research, authorship, and publication of this article.

ETHICAL COMPLIANCE

The authors have followed ethical standards in conducting the research and preparing the manuscript.

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