# Resistance levels of selected rice genotypes to *Sitophilus oryzae* L. and *Rhyzopertha dominica* F. infestations

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**Abstract**

The need to screen new rice genotypes for resistance to stored product insect pests is important to boost production and availability of rice for food security. Therefore, thirteen rice genotypes and varieties included ten interspecific rice genotypes from two crossed parents *Oryza sativa* (WAB 56-104) and *Oryza barthii* (IRGC 106107), the two parents and NERICA8 variety were collected from Africa Rice Center, International Institute of Tropical Agriculture (IITA) Ibadan, to examine their resistance level to infestation by *Sitophilus oryzae* L. and *Rhyzopertha dominica* F. The resistance of the varieties were assessed by artificial infestation with 12 unsexed adults each in 10 g of the rice varieties in four replicates under laboratory conditions of 26 ± 2°C temperature and 75 ± 5% relative humidity in a completely randomized design. Number of adult insect emergent, per cent grain damage, percent weight loss of infested samples and index of susceptibility were determined. Correlation analysis between nutritional contents of the varieties and infestation variables were also obtained. Results indicate differential responses of the two insects on the rice genotypes/varieties. The *O. barthii* parent was resistant, while the *O. sativa* parent was moderately resistant using the susceptibility index. Of the ten rice genotypes, G4, G3, G1, G7, G2, G10 and G9 were resistant in descending order, while G5 and G6 were moderately resistant, whereas only G8 was susceptible. NERICA8 was also found to be susceptible to infestation. In addition, the resistant grains had lower ash content. Modification in genetic variations and nutritional contents of new rice varieties may be a critical factor in insect resistant genotype pro-grammes to reduce post-harvest losses incurred by farmers.

**Keywords:** Rice resistant genotypes; *Rhyzopertha dominica; Oryzae sativa; Oryzae barthii; Sitophilus oryzae;* susceptibility index.

**Accepted:** 8 July 2019.

## Introduction

Rice is a national staple food and an increasingly important crop in Nigeria. It is grown on approximately 3.7 million hectares of land covering 10.6 percent of the 35 million hectares of land under cultivation (Candoni and Angelucci, 2013). The Federal Government had since 2015 under Anchor Borrower's Programme, embarked on strategy to make the country attain self-sufficiency in rice production by 2020 (Agro Nigeria, 2018). Nigeria produces more rice than any other country on the continent (Africa Rice, 2016), but this is not sufficient to feed her increasing population. The production–consumption gap in many Africa countries is large (Chougourou *et al*, 2013). To fill this gap, national and international research institutes have developed high yielding varieties in order to boost the local production of rice (Chougourou *et al*, 2013). To this end, Africa Rice Center under it breeding task force framework 2014 has specifically generated some interspecific progenies from crosses involving Africa wild rice *Oryzae barthii* (IRGC 106176) and Asian rice *Oryzae sativa* (WAB 56-104) (Semon, 2013). These varieties had been evaluated in the Preliminary Evaluation Trial (PET) throughout Africa (Semon, 2013). However, the greatest potential of *O. barthii* is probably as a source of resistance to various diseases affecting the Asian rice, *O. sativa* which is a high yielding and good quality species. These new interspecific varieties combine increased yield potential, good grain characteristics, insect pest and disease resistance as well as improved grain quality, good taste and aroma (Semon, 2013). Despite intensive efforts of integrated pest management (varietal development, quality seed production, good field management and appropriate production techniques dissemination), post-harvest and storage aspects are often overlooked (Santos *et al*, 2014). Unfortunately, the quantity and quality of rice can easily be reduced by several species of insects during storage. Hence, in addition to agronomic obstacles, storage insects are the major problems to attain rice self-sufficiency

http://dx.doi.org/10.4314/tzool.v17i1.7

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(Astuti *et al*, 2013). The storage losses of grains vary from 5-10 percent (Shafique and Chaudry, 2007). These losses can go as high as 20-80 per cent a few months after harvest if insects are not controlled (Baban and Bingham, 2014) due to improper storage conditions in hot and humid seasons. Rice is generally stored as paddy rice and potential internal storage insects of stored paddy include angoumois grain moth *Sitotroga cerealella* (Olivier), lesser grain borer, *Rhyzopertha dominica* (Fabricius), rice weevil, *Sitophilusoryzae* (Linnaeus), red flour beetle *Tribolium castaneum* (Herbst) and khapra beetle, *Trogoder magranarium* (Everts). Some properties of rice grains such as the integrity of the hull and rice hardness conferred some level of protection from stored-product insect pests (Chanbang *et al*, 2008a).

Infestation and damage of stored rice by rice weevil *Sitophilus oryzae* L. (Coleoptera: Curculionidae) often manifest in quality deterioration, weight loss and severe powdering of the grains. Most of the damage to grains is done by the larvae, which chew large and irregular holes into the endosperm leaving only the hull of the kernel (CABI, 2018).Lesser grain borer *Rhyzopertha dominica* F. (Coleoptera: Bostrichidae) is a cosmopolitan insect pest of stored grains (Arthur *et al*, 2012). This species is well adapted to dry conditions (Emekci*et al*, 2004) and is generally regarded as a strong flier, hence it can easily disperse from one storage facility to another and create new infestations (Stejskal*et al*, 2003; Khan and Marwat, 2004). Significant weight loss caused by both result larvae and mature adults through their feeding damage, respectively have been reported (Chanbang *et al*, 2008b). These losses due to insects attack leads to reduced profitability, affect consumers and contributes to malnutrition in countries that struggle to provide adequate food for their nutritional needs.

Previous studies on the resistance or susceptibility of new improved rice varieties such as the New Rice for Africa (NERICAs) to rice pests particularly *S. oryzae* and *R. dominica* have been studied (Chougourou *et al* 2013; Badii *et al* 2013). However, the resistance of the genotypes used in this study to these two major pests of stored cereals in the tropics are yet to be investigated. It is therefore imperative to routinely screen new improved crop varieties for resistance or susceptibility against damaging storage pests, as storage is a necessity in seed production system. This study was set up to assess the resistance of some selected rice varieties to *S. oryzae* and *R. dominica* infestation and also determine their nutritional contents which could confer resistance or susceptibility prior to their release to farmers.

## Materials and methods

### *Study site*

The experiment was conducted in 2014 in the Entomology Research Laboratory, Department of Zoology, University of Ibadan (07° 26′N and 03° 53′E), Nigeria. The study was carried out under laboratory conditions of 26 ± 2°C temperature and 75 ± 5% relative humidity.

### *Sitophilus oryzae and Rhyzopertha dominica stock cultures*

Adults of *S. oryzae* collected from infested rice samples at Africa Rice Store Room in Cotonou, Republic of Benin were reared on un-infested paddy rice samples inside a 2L plastic container. Adults of *R. dominica* collected from infested cassava chips in the laboratory were cultured on a mixture of un-infested dry cassava chips and maize substrates inside a 2L size plastic container. Both stock cultures were covered with muslin cloth to allow for aeration and fastened with rubber bands to prevent the insects from escaping and possible cross infestation. After 14 days of mating and oviposition, the adults were removed and the substrates containing the eggs were left undisturbed. Subsequent emerging adults (F1) were utilized as the parental generation for the paddy grain resistance experiment.

### *Rice varieties and pre-experimental procedure*

The samples of the rice genotypes and varieties used were obtained from Africa Rice Center, Ibadan Station of International Institute of Tropical Agriculture (IITA), Ibadan. The grains were kept in paper bags and pre-conditioned at -5°C inside a freezer for 3 days to get rid of any hidden pest, before their usage. After this treatment, the paddy grains were spread on normal white papers inside a wooden screen cage for 24 hours for stability at room temperature (Khan and Halder, 2012).

Thirteen rice genotypes and varieties tested for their resistance to *S. oryzae* and *R. dominica* in this study include: ten genotypes namely G1, G2, G3, G4, G5, G6, G7, G8, G9, G10 which are interspecific genotypes from crosses between *O. sativa* (WAB 56-104) and *O. barthii* (IRGC 106176), plus the parents and a NERICA 8 variety. The NERICA 8 was a known susceptible variety and was used as the susceptible check. The morphological description of the rice genotypes and varieties were assessed by placing randomly selected rice of each genotype or variety on a calibrated graph sheet (Sangeetha *et al*, 2013). An average of ten rice was calculated for each length and width measurements. Classification of rice based on length to width ratio was done according to USDA, (1994) that stated 3.4 mm or more (long grain), 2.3 to 3.3 mm (medium grain) and 2.2 mm or less (short grain) for classification of rice kernel.

### *Resistance studies and damage assessment*

Levels of resistance in rice varieties to *S. oryzae* and *R. dominica* infestations were determined in laboratory experiments. Ten grams of each rice varieties were weighed with an electric balance [Model: Soehnle Professional 9230 (Max 600g × 0.01)] and placed in 250 ml glass vials. According to (Chigoverah *et al*, 2014) with little modification, unsexed adult test insects (12 *S. oryzae* and 12 *R. dominica*) were infested separately into each vial. The vials were labeled, covered with muslin cloth and tightened with rubber bands to allow for aeration and to prevent escape of the insects. Each variety served as the treatment and was sub-replicated four times. The set-up was kept in a wooden screen cage (60cm x 30cm x 30cm). Two weeks after infestation, the insects are presumed to have mated and oviposited, therefore the paddies were sifted to remove all the adults. The paddy with all frass produced were returned into each vial and covered. The vials were held inside the cage for additional 6 weeks during which all F1 adults progenies had emerged. Adult emergence, percent grain damage, per cent weight loss and Dobie's susceptibility index were determined. Emerged F1 populations in each glass vial were removed and counted every other day until the end of the study when emergence did not occur again and all F1 progenies were expected to have emerged before the F2 generation started (Bashir, 2002). Each treatment was terminated when no emergence was recorded for 4 consecutive days (Ashamo, 2006). The total population of F1 adults which emerged in each replicate was recorded. Damaged grains due to insect boring activities were visually detected and separated from undamaged grains. Damaged (hollowed or riddled) grains in each vial were counted and the percent grain damage was calculated using the method given by Odeyemi and Daramola (2000) as:

Percent Grain Damage (% GD)

$$= \frac{\text{number of holedgrain}}{\text{total number of grains}} \times 100$$

The weight loss due to infestation was calculated using the 'count and weigh' method (Baban and Bingham Zivanovic, 2014):

Percent Weight Loss (% WL)

$$= \frac{[(Wu \times Nd) - (Wd \times Nu)]}{Wu \times (Nd + Nu)} \times 100$$

Where, Wu = weight of undamaged grains, Nu = number of undamaged grains, Wd = weight of damaged grains, Nd = number of damaged grains.

The susceptibility index (SI) was calculated using Dobie and Kilminster (1977) method given as:

$$\text{S.I} = \frac{(\log e\, F)}{D} \times 100$$

Where, *F* is the total number of F1 emergents and *D* is the median development period, estimated as the time (days) from the middle of the oviposition period to the emergence of 50% of the *F*1 generation. The susceptibility index ranged from 0 to 11 and was used to categorize the paddy rice varieties, where: 0-3 = resistant, 4-7 = moderately resistant, 8-10 = susceptible and e" 11 = highly susceptible (Dobie, 1974).

The nutritional (protein, ash, fat and carbohydrate) composition of the screened rice were analysed according to AOAC (2005) at the Department of Agronomy, University of Ibadan, Nigeria.

*Experimental design and data analyses*

The experiment was conducted using completely randomized design and statistical analyses were performed with SAS Version 9.0 (SAS Institute, Cary, NC) using the analysis of variance method. The General Linear Models (PROC GLM) procedure was used to determine significance with rice varietal as the main effect. Means when significant, were separated using Student-Newman-Keuls (SNK) test at $p<0.05$. Pearson Coefficient of correlation between the different parameters in each experiment were also determined (Steel and Torrie, 1980).

## Results

*Morphological and physical characteristics of rice genotypes and varieties*

The morphology of all the rice used in this study was classified as medium grain based on their length to width ratio (Table 1). The colour of each rice caryopsis when their outer hull was removed showed that all the rice were dull-white with the exception of IRGC 106176 which was reddish (Table 1).

*Resistance due to* S. oryzae *infestation*

The mean number of emerged adult insects from each of the rice genotypes used as shown in Table 2 were significantly different ($p<0.05$). Based on our result, variety IRGC 106176 was found to have fewer number of adult emergents (1.2 individuals). Among the genotypes, the number of emergents increased in genotypes G4, G10, G3 and G7 and varied between 1.8 and 4.8 insects. Number of *S. oryzae* was more in genotype G8, NERICA8 and WAB 56-104 varieties with 20.0, 16.8 and 13.8 *S. oryzae*, respectively. The egg-adult developmental time significantly differed across the varieties ($p<0.05$), the time taken ranged from 29.3 days for IRGC 106176 to 52.3 days for genotype G8. Table 2 shows that the most damaged varieties were G8 and NERICA8 having 8.4 and 6.2% damaged grains, respectively whereas G4, G10, and IRGC106176 had the least with 1.1, 1.3, and 1.4 damaged grains. The weight loss due to *S. oryzae* showed similar trend as the damaged grain. NERICA8 and G8 were observed to have the highest weight loss (2.7% and 2.5%), while G10 and G4 recorded the lowest loss with 0.3% and 0.5%, respectively. By categorization based on number of progeny emergence and mean developmental time (susceptibility index), IRGC106176 significantly differed and recorded the least susceptibility among the tested varieties. Genotype G8 and NERICA8 variety had the highest susceptibility while WAB 56-104, G5 and G6 recorded intermediate susceptibility (Table 2).

*Resistance due to R. dominica infestation*

Significant difference ($p<0.05$) between the rice varieties were observed in the number of emerged adult *R. dominica* (Table 3). The highest number was recorded from genotype G8 and NERICA 8 variety with 17.8 and 16.0 individuals, respectively. Genotypes G4, G9 and variety IRGC106176

**Table 1.** Description of 13 rice genotypes and varieties screened.

| Genotype/variety | Hybrid code | Length (mm) | Width (mm) | L/W ratio (mm) | Type of grain | Colour of caryopsis |
|---|---|---|---|---|---|---|
| G1 | ART 15-16-12-3-1-B-1-B-3-1 | 0.9±0.0 | 0.3±0.0 | 3.0 | Medium | Dull white |
| G2 | ART 15-19-5-4-1-1-1-B-1-1 | 0.9±0.0 | 0.3±0.0 | 3.0 | Medium | Dull white |
| G3 | ART 16-4-1-21-2-B-2-B-1-2 | 0.9±0.0 | 0.3±0.0 | 3.0 | Medium | Dull white |
| G4 | ART 16-9-29-10-4-1-1-B-1-1 | 0.9±0.0 | 0.3±0.0 | 3.0 | Medium | Dull white |
| G5 | ART 16-9-29-12-1-1-1-B-1-1 | 0.9±0.0 | 0.3±0.0 | 3.0 | Medium | Dull white |
| G6 | ART 16-9-29-12-1-1-2-B-1-1 | 0.9±0.0 | 0.3±0.0 | 3.0 | Medium | Dull white |
| G7 | ART 16-9-29-16-1-1-1-B-1-2 | 1.0±0.0 | 0.3±0.0 | 3.3 | Medium | Dull white |
| G8 | ART 15-16-45-1-B-1-1-B-1-2 | 0.9±0.0 | 0.3±0.0 | 3.0 | Medium | Dull white |
| G9 | ART 16-13-11-1-2-B-2-B-2-2 | 1.0±0.0 | 0.3±0.0 | 3.3 | Medium | Dull white |
| G10 | ART 16-13-14-1-1-1-1-B-1-1 | 0.9±0.0 | 0.3±0.0 | 3.0 | Medium | Dull white |
| IRGC 106176 | IRGC 106176 | 0.9±0.0 | 0.3±0.0 | 3.0 | Medium | Reddish |
| WAB 56-104 | WAB 56-104 | 1.0±0.0 | 0.3±0.0 | 3.3 | Medium | Dull white |
| NERICA 8 | NERICA 8 | 1.0±0.0 | 0.3±0.0 | 3.3 | Medium | Dull white |

**Table 2.** Progeny emergence, developmental time, percent grain damage, percent weight loss, susceptibility index and category of susceptibility of the rice genotypes and varieties due to *S. oryzae* infestation.

| Genotype/ variety | PE | MDT (days) | % GD | % WL | SI | Category |
|---|---|---|---|---|---|---|
| G1 | $6.3\pm1.0^{ef}$ | $46.8\pm0.5^{c}$ | $3.73\pm0.94^{b}$ | $1.0\pm0.2^{bc}$ | $3.8^{d}$ | Resistant |
| G2 | $6.3\pm1.4^{ef}$ | $46.5\pm0.7^{c}$ | $3.19\pm0.53^{b}$ | $0.7\pm0.2^{bc}$ | $3.8^{d}$ | Resistant |
| G3 | $4.8\pm1.4^{ef}$ | $48.5\pm0.7^{bc}$ | $2.44\pm0.81^{b}$ | $1.0\pm0.4^{bc}$ | $2.9^{de}$ | Resistant |
| G4 | $1.8\pm0.6^{f}$ | $51.3\pm0.3^{a}$ | $1.13\pm0.46^{b}$ | $0.5\pm0.2^{bc}$ | $1.2^{ef}$ | Resistant |
| G5 | $11.3\pm1.3^{cd}$ | $36.0\pm0.4^{d}$ | $3.90\pm0.74^{b}$ | $1.3\pm0.2^{bc}$ | $6.7^{c}$ | Moderately resistant |
| G6 | $7.8\pm1.4^{de}$ | $33.5\pm0.7^{e}$ | $2.9\pm0.6^{b}$ | $1.3\pm0.2^{bc}$ | $6.0^{c}$ | Moderately resistant |
| G7 | $4.8\pm1.1^{ef}$ | $48.0\pm0.9^{c}$ | $2.2\pm0.7^{b}$ | $0.9\pm0.4^{bc}$ | 3.1d[e] | Resistant |
| G8 | $20.0\pm2.5^{a}$ | $29.3\pm0.9^{f}$ | $8.4\pm0.8^{a}$ | $2.5\pm0.5^{a}$ | $10.2^{a}$ | Susceptible |
| G9 | $5.0\pm1.1^{ef}$ | $48.8\pm0.6^{bc}$ | $2.7\pm0.2^{b}$ | $1.3\pm0.1^{c}$ | 3.2d[e] | Resistant |
| G10 | $2.8\pm0.6^{ef}$ | $50.5\pm0.7^{ab}$ | $1.3\pm0.2^{b}$ | $0.3\pm0.2^{c}$ | 1.8d[ef] | Resistant |
| IRGC 106176 | $1.3\pm0.3^{f}$ | $52.3\pm0.8^{a}$ | $1.4\pm0.3^{b}$ | $0.7\pm0.1^{bc}$ | $0.3^{f}$ | Resistant |
| WAB 56-104 | $13.8\pm1.0^{bc}$ | $36.8\pm0.8^{d}$ | $2.6\pm0.3^{b}$ | $1.6\pm0.4^{b}$ | $7.1^{c}$ | Moderately resistant |
| NERICA8 | $16.8\pm1.6^{ab}$ | $32.3\pm0.5^{e}$ | $6.2\pm0.8^{a}$ | $2.7 \pm 0.1^{a}$ | $8.7^{b}$ | Susceptible |

*Mean ± SE in each column followed by different letters are significantly different at $p$>0.05 using SNK test.
PE: Progeny Emergence; MDT: Mean Developmental Time; GD: Grain Damage; WL: Weight Loss; SI: Susceptibility Index.

had the same number of emerged adults (1.8 individuals), while genotype G1 recorded the least emergence with 1.5 individuals. The mean time taken for development of the larvae into adult was significantly different and ranged from 35.8 days to 53.3 days. As a consequence of high number of emerged insects, varieties G8, NERICA8, G6 and WAB 56-104 were the most damaged with 9.2, 6.8, 3.2 and 2.7 grain damage per cent, respectively. Likewise, varieties G9, G1, IRGC106176, G7, and G4 had lower emerged number of insects recorded lower grain damaged ranging between 0.7 and 1.6 population. The highest per cent weight loss were observed on G8 (2.2%), NERICA8 (1.7%) and G6 (1.3%), while genotypes G9, G1, G3 and G10 showed the least weight loss (0.2, 0.4, 0.4 and 0.5%), respectively. From our results based on susceptibility index, G1, G4, G9, IRGC 106176, G3, G7, G2 and G10 were resistant, while G8 and NERICA 8 were susceptible. Moderate resistant to infestation was however recorded on genotypes G5, G6 and variety WAB 56-104 (Table 3).

### *Nutritional composition of rice genotypes/varieties*

The nutritional composition per 100 g of rice used in this study which comprised of protein, ash, fat and carbohydrate contents is presented in Table 4. The protein content (PC) value ranged from7.4-10.5 g while the ash content (AC) value ranged from 1.0- 2.0 g. Also, the fat content (FC) value ranged from 0.5-1.0 g while the carbohydrate (CHO) content ranged from 80.8-85.5 g across all the rice.

### *Correlation of S. oryzae infestation indices with nutritional content*

The result of the correlation with infestation indices of the rice varieties is shown in Table 5. The number of

**Table 3.** Progeny emergence, developmental period, percent damage and weight loss, susceptibility index and category of susceptibility of the different rice varieties due to *R. dominica* infestation**.**

| Genotype/ variety | PE | MDT (days) | % GD | % WL | SI | Category |
|---|---|---|---|---|---|---|
| G1 | $1.5\pm0.3^{e}$ | $52.3\pm0.3^{ab}$ | $1.4\pm0.2^{de}$ | $0.4\pm0.1^{cd}$ | $0.7^{e}$ | Resistant |
| G2 | $4.8\pm0.5^{de}$ | $51.8\pm0.9^{ab}$ | $2.4\pm0.3^{cd}$ | $0.7\pm0.1^{cd}$ | $3.0^{cd}$ | Resistant |
| G3 | $3.3\pm0.5^{de}$ | $53.0\pm0.4^{a}$ | $1.5\pm0.3^{de}$ | $0.4\pm0.1^{cd}$ | $2.2^{de}$ | Resistant |
| G4 | $1.8\pm0.5^{e}$ | $52.5\pm0.7^{ab}$ | $1.6\pm0.2^{de}$ | $0.6\pm0.2^{cd}$ | $0.9^{e}$ | Resistant |
| G5 | $7.3\pm1.1^{d}$ | $49.0\pm1.5^{abc}$ | $2.3\pm0.3^{cd}$ | $0.7\pm0.1^{cd}$ | $4.0^{bc}$ | Moderately resistant |
| G6 | $10.5\pm0.9^{c}$ | $45.8\pm1.4^{c}$ | $3.2\pm0.4^{c}$ | $1.3\pm0.2^{bc}$ | $5.1^{b}$ | Moderately resistant |
| G7 | $4.0\pm0.4^{de}$ | $52.3\pm0.3^{ab}$ | $1.6\pm0.2^{de}$ | $0.5\pm0.1^{cd}$ | $2.4^{cde}$ | Resistant |
| G8 | $17.8\pm1.7^{a}$ | $35.8\pm1.3^{d}$ | $9.2\pm0.3^{a}$ | $2.2\pm0.4^{a}$ | $8.1^{a}$ | Susceptible |
| G9 | $1.8\pm0.3^{e}$ | $53.3\pm0.3^{a}$ | $0.7\pm0.1^{e}$ | $0.2\pm0.0^{d}$ | $1.0^{e}$ | Resistant |
| G10 | $6.3\pm0.9^{de}$ | $51.3\pm0.3^{ab}$ | $1.9\pm0.3^{cde}$ | $0.5\pm0.1^{cd}$ | $3.5^{cd}$ | Resistant |
| IRGC 106176 | $1.8\pm0.3^{e}$ | $53.3\pm0.3^{a}$ | $1.5\pm0.2^{de}$ | $0.7\pm0.1^{cd}$ | $1.0^{e}$ | Resistant |
| WAB 56-104 | $13.3\pm1.0^{bc}$ | $48.5\pm0.3^{bc}$ | $2.7\pm0.3^{cd}$ | $0.9\pm0.1^{cd}$ | $5.3^{b}$ | Moderately resistant |
| NERICA8 | $16.0\pm2.7^{ab}$ | $37.8\pm2.1^{d}$ | $6.8\pm0.9^{b}$ | $1.7\pm0.4^{ab}$ | $7.4^{a}$ | Susceptible |

*Mean ± SE in each column followed by different letters are significantly different at $p>0.05$ using SNK test.
PE: Progeny Emergence; MDT: Mean Developmental Time; GD: Grain Damage; WL: Weight Loss; SI: Susceptibility Index.

**Table 4.** Nutritional content values per 100 g of rice genotypes and varieties used.

| Genotype/variety | PC (g) | AC (g) | FC (g) | CHO (g) |
|---|---|---|---|---|
| G1 | 9.8 | 1.1 | 0.5 | 83.7 |
| G2 | 8.1 | 1.1 | 0.6 | 84.9 |
| G3 | 10.2 | 1.1 | 1.0 | 81.1 |
| G4 | 9.1 | 1.0 | 0.5 | 84.8 |
| G5 | 9.5 | 1.5 | 0.8 | 83.6 |
| G6 | 8.8 | 1.6 | 0.8 | 85.5 |
| G7 | 9.5 | 1.1 | 0.5 | 84.6 |
| G8 | 9.1 | 2.0 | 0.5 | 82.5 |
| G9 | 8.4 | 1.1 | 0.5 | 85.1 |
| G10 | 10.5 | 1.2 | 0.6 | 82.4 |
| *O. barthii* | 8.8 | 1.0 | 1.0 | 80.8 |
| *O. sativa* | 8.4 | 2.0 | 1.0 | 82.1 |
| NERICA 8 | 7.4 | 2.0 | 0.6 | 83.3 |

PC: Protein Content; AC: Ash Content; FC: Fat Content; CHO: Carbohydrate Content.

**Table 5.** Correlation between nutritional content and *S. oryzae* infestation indices on rice varieties.

| Nutritional content | PE | GD | WL | SI | MDT | PC | AC | FC | CHO | L/W |
|---|---|---|---|---|---|---|---|---|---|---|
| PE | 1 | 0.90** | 0.93** | 0.98** | -0.92** | -0.41 | 0.93** | -0.066 | -0.08 | 0.63* |
| GD | | 1 | 0.87** | 0.88** | -0.80** | -0.32 | 0.72** | -0.30 | -0.02 | 0.50 |
| WL | | | 1 | 0.90** | -0.85** | -0.56* | 0.86** | -0.07 | -0.05 | 0.60* |
| SI | | | | 1 | -0.97** | -0.39 | 0.92** | -0.09 | 0.05 | 0.70* |
| MDT | | | | | 1 | 0.39 | -0.93** | 0.01 | -0.08 | -0.64* |

PE: Progeny Emergence; GD: Grain Damage; WL: Weight Loss; SI: Susceptibility Index; MDT: Mean Developmental Time; PC: Protein Content; AC: Ash Content; FC: Fat Content; CHO: Carbohydrate Content; L/W: Length/Width ratio.
*, **: indicate significance at $p<0.05$ and $p<0.01$, respectively.

*S. oryzae* adult emergence was positive and significantly correlated with grain damage, weight loss and length/width ratio (*r* = 0.90; 0.93 and 0.63, respectively). Similarly, susceptibility index positively correlated with weight loss (*r* = 0.90). Mean developmental time of *S. oryzae* negatively correlated with ash content (*r* = -0.93). The correlations of the ash content of the rice varieties with infestation indices were positive and significant.

*Correlation of R. dominica infestation indices with nutritional content*

The correlation of infestation indices with nutritional contents of the varieties used is recorded in Table 6. Significant correlations of susceptibility index and grain damage and weight loss (*r* = 0.89) were the same. Grain damage significantly correlated with weight loss (*r* = 0.97). The correlations between carbohydrate content and adult *R. dominica* emergence (*r* = -0.09), weight loss and protein content (*r* = -0.42), grain damage and fat (*r* = -0.22) were negative and not significant. Our result shows that negative and significant correlations existed between mean developmental time and progeny emergence, grain damage, weight loss and susceptibility index (*r* = -0.93; -0.97; -0.96; -0.93), respectively.

**Table 6.** Correlation between nutritional content and *R. dominica* infestation indices on rice varieties.

| Nutritional content | PE | GD | WL | SI | MDT | PC | AC | FC | CHO | L/W |
|---|---|---|---|---|---|---|---|---|---|---|
| PE | 1 | 0.89** | 0.90** | 0.99** | -0.93** | -0.41 | 0.97** | -0.01 | -0.09 | 0.61* |
| GD | | 1 | 0.97** | 0.89** | -0.97** | -0.30 | 0.77** | -0.22 | -0.13 | 0.45 |
| WL | | | 1 | 0.89 | -0.96** | -0.42 | 0.82** | -0.08 | -0.09 | 0.43 |
| SI | | | | 1 | -0.93** | -0.35 | 0.93** | -0.01 | 0.09 | 0.58* |
| MDT | | | | | 1 | 0.40 | -0.87** | 0.17 | -0.04 | -0.56* |

PE: Progeny Emergence; GD: Grain Damage; WL: Weight Loss; SI: Susceptibility Index; MDT: Mean Developmental Time; PC: Protein Content; AC: Ash Content; FC: Fat Content; CHO: Carbohydrate Content; L/W: Length/Width ratio. *, **: indicate significance at $p< 0.05$ and $p< 0.01$ respectively.

## Discussion

Morphological and physical properties of grains have been reported to play an important role in the natural varietal resistance against a wide range of insects including *S. oryzae* and *R. dominica* (Ahmed *et al*, 2002; Shafique and Chaudry, 2007). Chanbang *et al* (2008a, 2008b) cited kernel hardness, husk protection, kernel size and the texture of the grain envelop as the main physical properties assisting cereals to resist insect pest infestation, these submissions were evident from this study. The small seed size, tightness of it hull and reddish caryopsis of IRGC 106176 could explain why it was resistant to *S. oryzae* and *R. dominica* attacks. However for genotype G8, it could be attributed to its grain size and this is in good agreement with earlier work by Stejskal and Kucerova (1996) who reported that *S. oryzae* preferred larger grains for oviposition. Similarly, oviposition and development are favoured by bigger grains and this is evident in the number of F1 adult emergence and the percentage grain damage (Ashamo, 2006). The susceptible varieties have bigger grains, therefore oviposition and development were favoured in them as shown in this study. A positive and significant correlation between length/width ratio and insect infestation was observed in the result. This corresponds to Dobie (1974), who reported a positive correlation between length/breadth ratio and insect incidence on rice varieties.

The rate at which insects increase in numbers on stored produce depend on two factors namely; number of progeny produced by each parent and the time taken for progeny to develop into adults. Our results showed that IRGC 106176 and G4 had least number of F1 adult emergence, while G8 and NERICA 8 recorded the highest emergence. From the resistant rice varieties, the cumulative reduction of the insect population may presumably be due to the failure of adults and larvae to feed adequately, consequently leading to high mortality of larvae and adults, low oviposition and hatching of the eggs, while on the other hand, population increased on the susceptible varieties. Developmental time was significantly prolonged in the resistant varieties and was shortest in the susceptible varieties. The rapid development of the insects in the susceptible varieties suggests that *S. oryzae* and *R. dominica* have high reproductive ability in their preferred host. Chougourou *et al* (2013) stated that the situation may be due to many factors but genetic, physical, morphological and biochemical properties could be considered as the predominant factors. The genetic factor could be related to secondary metabolite compounds (Santos *et al* 2014) in the genotypes. Genotype G8 which is highly susceptible in this study could have lost it resistant gene due to meiotic event and selection process during breeding.

Although, feeding damage was low on the rice varieties used, genotype G8 and NERICA8 variety suffered maximum damage while genotypes G4 and G10, which displayed good resistance, had the lowest percentage grain damage. Rice kernel quality deterioration and severe powdering of the grains resulted from the feeding activities of both pests. Singh *et al* (1984) stated that the number of emerging adults determines the extent of their damage, and consequently grains permitting more rapid and higher levels of adult emergence will be more extensively damaged. Resistant genotypes G4 and G10 had the lowest percentage weight loss, while genotype G8 and NERICA 8 recorded the highest weight loss. Percentage weight loss has been reported to be a good indication of paddy rice resistance (Santos *et al*, 2014). Weight loss resulting from the quantity of materials consumed by the developing larvae correlated positively with the seed susceptibility index as recorded in our result. This corresponds with Badii *et al* (2013) that reported that weight loss of rice is generally highly correlated with susceptibility index.

The Dobie (1974) susceptibility index which is a measure of progeny production and scaled from 0 (resistant) – 11 (highly susceptible) indicated the comparative resistance of the varieties in this study. Therefore, variety IRGC 106176 and genotypes G4, G3, G1, G7, G2, G10, G9 were most resistant, while genotypes G5, G6 and variety WAB 56-104 were moderately resistant to *S. oryzae* and *R. dominica* infestations. In addition, genotype G8 and NERICA8 variety are susceptible to the two insect attacks. NERICA 8 variety which have been observed among NERICA rice varieties as a susceptible variety (Chougourou *et al*, 2013; Badii *et al*, 2013; Santos *et al*, 2014) and used as the susceptibility check was found to maintain its susceptibility to *S. oryzae* and *R. dominica* in this study. The nutritional composition of rice varieties and genotypes in this study varied. Nutritional contents of rice which include protein, fat, carbohydrate and ash contents have been reported to be responsible for susceptibility to Angoumois grain moth, *Sitotroga cerealella* infestation (Rizwana *et al*, 2011). Based on our results, the correlation between fat, protein, carbohydrate and insect infestations on the varieties are not significant, suggesting that the rice varietal resistance or susceptibility is irrespective of these rice nutritional compositions. However, ash content was positive and significantly correlated with infestation indices such as adult insect emergence, grain damage, weight loss, and susceptibility index, suggesting that the relative resistance to infestation by *R. dominica* and *S. oryzae* may likely be conferred by ash content among other factors. Ash content also correlated negatively with the mean developmental time of *S. oryzae* and *R. dominica*. This agreed with Astuti *et al* (2013) and Demissie *et al* (2015) who reported similar results. This indicates that the rice varieties with high ash content may support high number of progeny with fast developmental time and consequently be susceptible to *S. oryzae* and *R. dominica* attacks.

## Conclusion

This study indicates that many of the rice varieties screened were resistant to *S. oryzae* and *R. dominica* infestations. However, only genotype G8 and variety NERICA8 were found to be susceptible, while IRGC 106176 (*O. barthii* parent) was resistant to *S. oryzae* and *R. dominica*. Therefore the resistant genotypes certainly would have inherited a predominant resistance gene from their parents since one of the parent was a resistant variety. The rice variety with the lower ash content may be resistant, while rice varieties with higher ash content may be susceptible to *S. oryzae* and *R. dominica* infestations. Modifications in nutritional contents of new rice varieties could be an important factor in insect resistant genotype pro-grammes by breeding rice varieties with low ash content. Hence, the insect resistant genotypes screened could offer sustainable food security in all the African countries where the genotypes are set to be released.

**Acknowledgement**

We are grateful to the Africa Rice Center, Ibadan Research Station of International Institute of Tropical Agriculture (IITA), Oyo State, Nigeria, for the rice varieties used.

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**Citation:** Ajao, S. K., Popoola, K. O., Mande, S. and Togola, A.
Resistance levels of selected rice genotypes to *Sitophilus oryzae* L.
and *Rhyzopertha dominica* F. infestations.
http://dx.doi.org/10.4314/tzool.v17i1.7

*The Zoologist, 17:* 39-46 December 2019, ISSN 1596 972X.
Zoological Society of Nigeria.