Relative Susceptibility and Proximate Composition of Some Imported and Local Rice Varieties to Infestation and Damage by *Sitophilus oryzae* L. (Coleoptera: Curculionidae)

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**Abstract** Ten rice varieties were assessed for their comparative susceptibility and proximate composition to post harvest infestation and damage by *Sitophilus oryzae* L. (Coleoptera: Curculionidae). The damage parameters used to compare the susceptibility of the rice varieties to *S. oryzae* were; percentage mortality 4 weeks after adult insects infestation, number of F1 progeny, percentage grains weight loss and F2 adult emergence. Four weeks post infestation (WPI), almost all the adults introduced to ITA 315 had died (95% mortality rate) which was significantly (P<0.05) higher than death recorded in all other varieties, except Caprice (where 92.5% mortality was recorded). At 8 WPI, there were significant differences (P<0.05) in F1 adults emergence. The highest mean number of F1 adult emergence was recorded for Isan, which was significantly higher (P<0.05) than adult emergence (F1) in other varieties. The lowest mean number of F1 adults was recorded in ITA 315. At 8 and 12 WPI, there was significant difference (P<0.05) in weight loss among the ten varieties. Weight loss was similar among the imported varieties and Ayede Ekiti rice. There was also no difference (P>0.05) in the weight loss of Igbemo, Ofada and Erio varieties. Highest and lowest weight loss was obtained for Isan and ITA 315, at week 8 and 12 respectively. The extent of damage done by the introduced adult *S. oryzae* were observed to be reduced in ITA 315, Caprice, ITA 257 and Cisadene varieties, as they may have found it hard to puncture into or oviposit in the grains, resulting in reduced weight loss, and low F1 progeny and F2 adult emergence. Grain hardness, moisture content and anti-nutrient compositions of the selected varieties were investigated whether it may be used as indicators of resistance. Only moisture content could be established as an indicator of resistance, as the grain moisture content was significantly positively correlated with both F1 and F2 adult emergence. The imported varieties which recorded higher resistance had lower moisture content compared to the local varieties. Grain hardness and anti-nutrient composition did not affect susceptibility of the rice varieties to infestation and damage of *S. oryzae* because there was no significant (P>0.05) correlation between the two variables and susceptibility to the weevil.

**Keywords** Adult emergence; Anti-nutrient compositions; Grain hardness; Grain moisture content; Mortality; Weight loss

**Introduction** Rice as a cereal grain, it is the most important staple food for a large part of the world's human population, especially in Asia and the West Indies. It is the grain with the second-highest worldwide production, after maize (corn), according to data for 2010 (FAO, 2011). Rice is the staple food of over half the world's population. It is the predominant dietary energy source for 17 countries in Asia and the Pacific, 9 countries in North and South America and 8 countries in Africa. Rice provides 20% of the world's dietary energy supply, while wheat supplies 19% and maize 5% (FAO, 2004). it is central to the food security of over half the world population.

The high and rising population growth rate in Africa has led to the high demand for rice in Sub Saharan Africa and its consumption is growing faster than that
of any other staple food in Africa (WARDA, 2008). Four out of the eleven largest rice importing countries in the world are within Sub Saharan Africa with Nigeria as the world’s largest importer (WARDA, 2007).

The rice plant is vulnerable to attack by various kinds of insects from the time the seed is planted until the grain is harvested, during storage and distribution. Rice is often attacked by various storage insects, among these are *Sitophilus oryzae* Linn and *Sitophilus zeamais* Motsch. The most important and most destructive of these insect pests is *S. oryzae* which can fly to the field and attack grain before it is harvested in tropical and sub-tropical regions. Most of the damage to grains is done by the larvae, which devour most the whole endosperm leaving only the hull. (Nilsa and Bosque–Perez, 1992), causing between 25% to 100% post-harvest losses in storage (Okonkwo, 1998). They build up in large numbers in stored grain and causes unflavored taste and odour which made rice unpalatable for consumer. (Metcalf, 1994; Charles et al., 2003). In addition to causing direct loss, *S. oryzae* also reduces seed viability and contaminates the product with excrements, thus reducing the market and nutritional value of the food (Lale, 1992). Owing to their insidious feeding habits, they are often undetected until damage has occurred.

Rice varieties exhibit varying degrees of susceptibility to damage by insects. One of the ways of reducing post-harvest losses of grains is breeding for varietal resistance. The factors that confer resistance to the grains against infestation by a variety of storage insects are varied. Stout et al. (2001) documented significant variation in the susceptibilities of modern commercial varieties to infestation by weevil larvae. Despite these studies, very little effort has been made to incorporate weevil resistance into commercial varieties or to integrate plant resistance into management programs for this insect. Various works have been done on the resistance or susceptibility of different varieties of rice to attack by the rice weevil (Enobakhare and Wey, 1996; Joda, 1998; Ashamo, 2005). However, there are a lot of varieties yet to be tested against *S. oryzae* infestation, especially the local varieties. Therefore in this study, the susceptibility of some selected imported rice varieties and some local rice varieties to *S. oryzae* infestation were investigated under laboratory conditions.

### 1 Material and Methods

#### 1.1 Experimental location and condition

The study was conducted in the Research Laboratory of the Department of Crop, Soil and Pest Management of the Federal University of Technology, Akure (7°16′N, 5°12′E) Ondo State, Nigeria; under ambient laboratory conditions of (28 ± 4)°C and (65 ± 10)% relative humidity.

#### 1.2 Source of rice substrates

The improved rice varieties used for this experiment were collected from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria. While the imported varieties were purchase from Erekesan market, Akure, Nigeria and the local varieties were sourced from the various growing localities associated with the various varieties in Nigeria. The varieties and some of their characteristics are provided in Table 1.

| Variety       | Local name          | Colour     | Type      | Shape       | Form cultivated |
|---------------|---------------------|------------|-----------|-------------|-----------------|
| Imported      |                     |            |           |             |                 |
| Cisadene      |                     | White      | Short grain| Fairly robust| Lowland         |
| Caprice       | Aroso               | Shiny brown| Long grain | Slender     | Upland          |
| Improved      |                     |            |           |             |                 |
| ITA257/Faro 45| Yellow Mama Africa  | Yellow white| Long grain | Robust     | Upland          |
| ITA 315/Faro 49| Sara Portland Rice | Dirty white| Short grain | Robust     | Upland          |
| ITA 222/ Faro 36 Local | White Mama Africa | White | Long grain | Fairly robust | Lowland         |
| Isan rice     |                     | Dirty white| Short grain | Robust     | Lowland         |
| Igbemo rice   |                     | Dull white  | Long grain | Fairly robust| Upland          |
| Ofada rice    |                     | Dirty white| Short grain | Robust     | Upland          |
| Erio rice     |                     | Dirty white| Short grain | Robust     | Upland          |
| Ayede Ekiti rice |                 | Dull white  | Short grain | Robust     | Upland          |

Table 1 Morphological characteristics of the selected rice varieties used in the experiment
The rice varieties were sterilized in a deep freezer for 21 days. This was done to destroy any mites, larva, pupa or eggs of insect and adult insects that may be contained in the rice samples (Wee and Nick, 1998). The rice varieties were placed in jars and then left in the laboratory for seven (2) days so that the grains will acclimatize to ambient conditions.

1.3 Insect culture and maintenance
Adult rice weevils, *S. oryzae* were obtained from naturally infested rice grain from a cereal store in Ado Ekiti, Nigeria. Cultures for the study were established on a clean highly susceptible local rice variety. The weevils were introduced into the jar containing this rice variety and they were allowed to oviposit for a period of 18 days after which they were removed from the medium and discarded. The grains were returned to the culture jar and left undisturbed until the weevil completely emerged after 40 days.

1.4 Determination of grain hardness
Twenty grams (20 g) of each of the 5 local varieties and 5 imported varieties (Table 1) were weighed into Petri dishes, in 4 replications. The seed hardness was estimated using a California Bearing Ratio (CBR) Machine, which measured the force needed to crush the seeds in Newton. Five randomly selected grains of each of the rice varieties were individually crushed using the CBR machine and the readings recorded. The mean value of the force required to crush each of the varieties (in Newton) was then computed.

1.5 Mortality, F1 Progeny emergence and damage to rice varieties by *S. oryzae*
Four replicates of 20g each rice variety were placed in 50ml transparent containers. The containers were covered with lids with mesh perforation to allow for aeration. Five freshly emerged male and five female adults *S. oryzae* were introduced into each 20g lot of each variety. The weevils were allowed to feed and oviposit for a period of 28 days. During this period, mortality of *S. oryzae* was determined from daily counts of dead adults after which all surviving adults were removed, according to Onolemhemhen and Oigiangbe (1991).

Adult *S. oryzae* was presumed dead, if it failed to move when touched with a spatula. Thereafter, all weevils were sieved out. The experimental containers were then kept in the laboratory undisturbed until emergence of F1 generation. Thereafter the samples were inspected every other day for the emergence of F1 adult *S. oryzae*. Newly emerged F1 adults of *S. oryzae* were counted and removed until no emergence was recorded for five (5) consecutive days to prevent interference with F2 generation. Eight (8) WPI, the F1 generation had completely emerged. The adult emergence for each of the varieties was recorded as F1 adult emergence and the weight obtained for each of the samples.

The experimental containers were then left undisturbed for the F2 generation to emerge. The emergence was monitored until no emergence was noticed for about five days. The adult emergence for each of the varieties was recorded as F2 adult emergence and the weight loss of each of the ten varieties obtained.

Percentage mortality of introduced weevils was calculated at 4 WPI. The total number of adult emergence at 8 weeks and 12 WPI of parent weevils and grain loss at week 8 and week 12 were calculated.

1.6 Calculation of index of susceptibility
The index of susceptibility was determined as follows: Index of susceptibility (SI) = (Natural log F x 100)/D, where F is total number of F1 adult insects counted, D is median developmental period in days. Median developmental period is defined as the time from the middle of oviposition period until the emergence of 50% of the F1 generation. (Dobie, 1974)

1.7 Laboratory analysis of rice samples
Proximate Analysis was carried out to determine the ash, fat, mineral, crude fibre, moisture content and crude protein contents of each of the varieties.

1.8 Determination of moisture content
The moisture content was determined by using oven-drying method. Clean and dry petri-dishes were weighed by using Mettler balance and their respective weight were recorded (W1). 5g of each the sample was weighed into the dishes (W2) spreading as much as possible. The petri-dishes containing the sample were transferred into the oven maintained at 105°C and dried for about three hours. After three hours, they
were transferred to the desiccator to cool and then weighed. This process was continued until a constant weight \(W_3\) was obtained. The loss in weight during drying in percentage was taken to be the percentage moisture content. (A.O.A.C, 1990)

\[
\% \text{ Moisture} = \frac{\text{loss in weight due to drying}}{\text{Weight of sample taken}} \times 100
\]

1.9 Determination of ash

One gram (1g) of finely ground sample was weighed into clean dried pre-weighed crucibles with lid (\(W_1\)). The organic matter was burnt off using flame until the samples became charred. The crucibles were then transferred to the muffle furnace set at 550°C. Ashing was continued until a light grey or white ash was obtained. The crucibles were then cooled in a desiccator and weighed (\(W_2\)). (A.O.A.C, 1990)

\[
\% \text{ Ash} = \frac{W_2 - W_1}{\text{Weight of sample}} \times 100
\]

1.10 Mineral content determination

The ash obtained in 3.6.2 was dissolved in 25ml of 10% HCl and made up to the mark in 100ml standard flask with distilled water. The mineral content of each of the samples were analysed using Atomic Absorption Spectrophotometer. (Oshodi, 1992)

1.11 Fat determination

Clean and dried thimble was weighed (\(W_1\)) and 5g oven-dried sample were added and re-weighed (\(W_2\)). 500ml round bottom flask was filled with petroleum ether (40–60°C) up to 375ml of the flask. Soxhlet extractor was fixed with a reflux condenser to adjust the heat source so that the solvent boils gently, the samples were put inside the thimble and inserted into the Soxhlet apparatus and extraction under reflux was carried out with petroleum ether (40–60°C) for 6 hours. After the barrel of the extractor is empty, the condenser was removed and the thimble was removed, taken into the oven at 100°C for one hour and later cooled in the desiccator and weighed again (\(W_3\)). (A.O.A.C, 1990)

\[
\% \text{ Fat} = \frac{\text{Weight loss of sample (extracted fat)}}{\text{Original weight of sample}} \times 100
\]

\[
= \frac{W_2 - W_3}{W_2 - W_1} \times 100
\]

1.12 Crude protein determination

One gram (1g) each of the samples was weighed into the Micro Kjeldahl digestion flask and one tablet of selenium catalyst were added. The mixture was digested on an electro thermal heater until clear solution was obtained. The flask was allowed to cool after which the solution was diluted with distilled water to 50ml and 5ml of the solution was transferred into the distillation apparatus, 5ml of 2% boric acid was pipette into a 100ml conical flask (the receiver flask) and four drops of screened methyl red indicators were added. Fifty percent NaOH was continually added to the digested sample until the solution turned cloudy which indicated that the solution had become alkaline.

Then distillation was carried out into the boric acid solution in the receiver flask with the delivery tube below the acid level. As distillation was going on, the pink colour solution of the receiver flask turned blue indicating the presence of ammonia. Distillation was continued until the content of the flask was about 50ml after which the delivery of the condenser was rinsed with distilled water. The resulting solution in the conical flask was then titrated with 0.1M HCl.

\[
\% \text{ Nitrogen} = \frac{\text{Titre value x 0.1 HCl x 0.014 x 100 x 50/5}}{\text{Original weight of sample}}
\]

1.13 Determination of crude fibre

Two gram (2.0 g) of the sample (\(W_1\)) was weighed into 1L conical flask. 200 ml of boiling 1.25% of \(\text{H}_2\text{SO}_4\) was added and boiled gently for 30 minutes. The mixture was filtered through muslin cloth and rinsed well with hot distilled water. The sample was scrapped back into the flask with spatula and 200 ml of boiling 1.25% NaOH was added and allowed to boil gently for 30 minutes. It was filtered through muslin cloth and the residue washed thoroughly with hot distilled water and then rinsed with 10% HCl twice with industrial methylated spirit and rinsed to drain dry, then the residue was scrapped into a crucible, dried in the oven at 105°C, cooled in a desiccator and weighed again (\(W_3\)). (Joslyn, 1970)

1.14 Analysis of anti nutrients

Chemical analysis was carried out on each of the varieties to test for the Phenolic Content, Chlorogenic Acid Content, Tannin Content and Amylose Content.
1.15 Determination of phytin
Four gram (4 g) of finely ground samples were soaked in 100 cm$^3$ 2 % HCl for 3 hours and then filtered. 25cm$^3$ of the filtrate was placed in a 100 cm$^3$ conical flask and 5cm$^3$ of 0.03% Ammonium thiocyanide (NH$_4$SCN) solution was then added as indicator. 50cm$^3$ of distilled water was then added to give it the proper acidity. This was titrated with ferric chloride solution which contained about 0.005 mg of Fe per cm$^3$ of FeCl$_3$. The equivalent was obtained from this, the phytate content in mg/100g was calculated. (Young and Graves, 1940)

Iron equivalent = Titre value x 1.95

Phytic acid = Titre value x 1.95 x 1.19 x 3.55 mg/phytic acid

Therefore; % Phytic acid = \[\alpha \times \frac{8.24}{1000} \times \frac{100}{\text{Weight of sample}}\]

Where $\alpha$ = titre value.

1.16 Determination of tannin
Two hundred (200 mg) of finely ground sample was weighed into a 50 ml sample bottle. 100ml of 70% aqueous acetone was added and properly covered. The bottles were put in an ice bath shaker and shaken for 2 hours at 30°C. Each solution was then centrifuged and supernatant stored in ice. 0.2ml of each solution was pipette into test tubes and 0.8ml of distilled water was added. Standard tannic acid solutions were prepared from 0.5mg/ml stock and the solution made up to 1ml with distilled water. 0.5 ml folin- Ciocalteau reagent added. After 3 mins, 2 ml of 20% Na$_2$CO$_3$ solution was added to each tube and then, mixed thoroughly. The tubes were placed in boiling water for exactly one min, cooled and the absorbance measured at 650nm against a reagent blank. A standard curve prepared using different concentration of catechol. From the standard curve, the concentration of phenols in the test sample was obtained and expressed as mg/100g material. (Malik and Singh, 1980)

1.17 Determination of oxylate
One gram (1 g) of the sample was weighed into 100 ml conical flask. 75 ml of 1.5N H$_2$SO$_4$ was added and the solution was carefully stirred intermittently with a magnetic stirrer for about 1hr and then filtered using filter paper. 25 ml of sample filtrate (extract) was collected and titrated hot (80–90°C) against 0.1N KMnO$_4$ solution to the point when a faint pink colour appeared that persisted for at least 30 seconds. (Day and Underwood, 1986)

1.18 Determination of phenols
One gram (1 g) of the sample was weighed and grounded with a pestle and mortar in 10-time volume of 80% ethanol. The homogenate was centrifuged at 10,000 rpm for 20 mins. The supernatant, kept, and the residue was re-extracted with five times the volume of 80% ethanol. The supernatant was centrifuged, pool and evaporated to dryness, and then the residue was dissolved in 5ml distilled water. Different aliquots (0.2 to 2 ml) was pipetted into test tubes. The volume in each of the tubes was made up to 3ml with water. 0.5 ml of Folin- Ciocalteau reagent added. After 3 mins, 2 ml of 20% Na$_2$CO$_3$ solution was added to each tube and then, mixed thoroughly. The tubes were placed in boiling water for exactly one min, cooled and the absorbance measured at 650nm against a reagent blank. A standard curve prepared using different concentration of catechol. From the standard curve, the concentration of phenols in the test sample was obtained and expressed as mg/100g material. (Malik and Singh, 1980)

1.19 Chlorogenic acid determination
A known quantity of defatted sunflower meal was refluxed twice in 80% ethanol (adjusted to PH 4.0 with 2.5N HCL) for 30mins (125ml to 1g meal). The precipitate was discarded and 250ml of the extract collected. 0.5ml samples was removed and dried in a vacuum oven at 50°C and 700mm pressure for 2hours. Dried extract was dissolved in 4.75ml of acetone. 0.25ml of TiCl$_4$ was added and the colour read at 450nm against a reagent blank (acetone plus TiCl$_4$). Similarly, the standards was treated with TiCl$_4$ and read the colour intensity. A standard curve was drawn to find out the chlorogenic acid content in the sample. Chlorogenic acid content expressed as g per 100g sample (Aletor and Omodara, 1994)

1.20 Statistical analysis
Data obtained from the Research were subjected to the analysis of variance (ANOVA) using SPSS 15.0. Where necessary, data were transformed before analysis;
the adult emergence was transformed (using +0.5 square root transformation), mortality rate and percentage weight loss were arc sine transformed. Tukey test at 5% level of probability was used to separate significant differences between treatment means. Correlation of Adult emergence at 8 and 12 weeks with each of the anti-nutrient, grain moisture content and grain hardness was carried out. Percentage grains weight loss was also correlated with F₁ and F₂ emergence, as well as grain hardness with adult mortality, F₁ and F₂ adult emergence.

### 2 Results

Within four weeks of infestation, mortality of weevils introduced into ITA 315 was significantly higher (P<0.05) than death recorded in all other varieties except Caprice with 92.5% mortality, ITA 257 (85.0% mortality), ITA 222 (85.0% mortality) and Cisadene, (82.5% mortality). During this period, lowest mortality occurred in Isan (15.0% mortality), Igbemo (25.0% mortality) and, Ofada, (60% mortality) respectively (Table 2).

| S/N | Rice variety          | Mean adult mortality ± S.E of adult in 4 weeks |
|-----|-----------------------|---------------------------------------------|
| 1.  | Cisadene              | 82.5 ± 5.00bc                               |
| 2.  | Caprice               | 92.5 ± 9.57c                                |
| 3.  | ITA257/Faro 45        | 85.0 ± 5.77bc                               |
| 4.  | ITA 315/Faro 49       | 95.0 ± 5.77c                                |
| 5.  | ITA 222/ Faro 36      | 85.0 ± 5.77bc                               |
| 6.  | Isan rice             | 15.0 ± 5.77a                                |
| 7.  | Igbemo rice           | 25.0 ± 17.32a                               |
| 8.  | Ofada rice            | 60.0 ± 8.16b                                |
| 9.  | Erio rice             | 62.5 ±17.08b                                |
| 10. | Ayede Ekiti rice      | 65.0 ±17.32b                                |

Means in each column bearing the same letters are not significantly different at the 5% level of probability by Tukey test.

At Eight (8) WPI, there were significant differences (P<0.05) in the emergence of F₁ adults (Table 3). The highest mean number of F₁ adult emergence was recorded for Isan was 70 ± 1.30, which was significantly higher (P<0.05) than adult emergence (F₁) in other varieties. The lowest mean number of F₁ adults was recorded in ITA 315 (9.25 ± 0.77). While, at 12 (P<0.05) there were significant differences (P<0.05) among the rice varieties in the emergence of F₂ adults with the highest mean number of F₂ adults recorded in Isan with 176.75 ± 1.57 and Ayede with 149.25 ± 1.47, which was significantly higher (P<0.05) than the F₂ adult emergence recorded in other varieties. The lowest mean number of F₂ adults was recorded in ITA 315 (16.00 ± 1.00). There was no significant difference (P>0.05) in F₂ adult emergence between Ofada and Erio rice varieties. (Table 3).

| S/N | Rice variety          | Mean adult mortality ± S.E of adult in 4 weeks |
|-----|-----------------------|---------------------------------------------|
| 1.  | Cisadene              | 82.5 ± 5.00bc                               |
| 2.  | Caprice               | 92.5 ± 9.57c                                |
| 3.  | ITA257/Faro 45        | 85.0 ± 5.77bc                               |
| 4.  | ITA 315/Faro 49       | 95.0 ± 5.77c                                |
| 5.  | ITA 222/ Faro 36      | 85.0 ± 5.77bc                               |
| 6.  | Isan rice             | 15.0 ± 5.77a                                |
| 7.  | Igbemo rice           | 25.0 ± 17.32a                               |
| 8.  | Ofada rice            | 60.0 ± 8.16b                                |
| 9.  | Erio rice             | 62.5 ±17.08b                                |
| 10. | Ayede Ekiti rice      | 65.0 ±17.32b                                |

Means in each column bearing the same letters are not significantly different at the 5% level of probability by Tukey test.

Table 4 shows the mean weight loss in grams of different varieties of rice at 8 and 12 WPI. There was significant difference (P<0.05) in weight loss among the ten varieties. Weight loss was similar among the imported varieties and Ayede Ekiti rice. There was also no difference (P>0.05) in the weight loss of Igbemo, Ofada and Erio varieties. Highest weight loss (1.80±0.83) was obtained for Isan with the lowest (0.23±0.13) in ITA 315.

At 12 WPI, weight reduction was lowest in ITA 315 (0.53±0.21), which was significantly different (P<0.05) from other nine varieties. Highest weight reduction
Table 3 Adult emergence of *S. oryzae* at 8 and 12 WPI of different rice varieties

| Rice variety       | Mean number of F1 and F2 adult emergence ± S.E | Week 8 (F1) | Week 12 (F2) |
|--------------------|-----------------------------------------------|-------------|--------------|
| **Imported**       |                                               |             |              |
| Cisadene           | 18.75 ± 0.82ab                                | 69.00 ± 0.67cd |
| Caprice            | 16.50 ± 0.61ab                                | 62.00 ± 0.74bcd |
| **Improved**       |                                               |             |              |
| ITA257/Faro 45     | 17.50 ± 1.08ab                                | 31.75 ± 1.44abc |
| ITA 315/Faro 49    | 9.25 ± 0.77a                                  | 16.00 ± 1.00a  |
| ITA 222/ Faro 36   | 13.00 ± 1.33a                                 | 28.50 ± 1.00ab |
| **Local**          |                                               |             |              |
| Isan rice          | 70.00 ± 1.30d                                 | 176.75 ± 1.57e |
| Igbemo rice        | 38.00 ± 0.35bed                               | 82.50 ± 0.27de |
| Ofada rice         | 35.25 ± 0.50bc                                | 143.50 ± 1.78ef |
| Erio rice          | 52.25 ± 1.32gcd                              | 131.25 ± 1.56ef |
| Ayede Ekiti rice   | 61.50 ± 0.68cd                                | 149.25 ± 1.47e |

Table 4 Weight loss in grains of different varieties of rice, 8 and 12 WPI

| Rice Variety       | Mean weight loss (g) ± S.E | Mean weight loss (g) ± S.E |
|--------------------|---------------------------|---------------------------|
| **Imported**       |                           |                           |
| Cisadene           | 0.36 ± 0.17a              | 1.43 ± 0.43abc            |
| Caprice            | 0.42 ± 0.10a              | 1.20 ± 0.20ab             |
| **Improved**       |                           |                           |
| ITA257/Faro 45     | 0.34 ± 0.20a              | 0.72 ± 0.42ab             |
| ITA 315/Faro 49    | 0.23 ± 0.13a              | 0.53 ± 0.21a              |
| ITA 222/ Faro 36   | 0.30 ± 0.03a              | 0.73 ± 0.09ab             |
| **Local**          |                           |                           |
| Isan rice          | 1.80 ± 0.83b              | 3.52 ± 0.71c              |
| Igbemo rice        | 0.90 ± 0.94ab             | 3.39 ± 2.18c              |
| Ofada rice         | 0.80 ± 0.17ab             | 2.50 ± 0.94abc            |
| Erio rice          | 0.89 ± 0.41ab             | 2.72 ± 1.15bc             |
| Ayede Ekiti rice   | 0.72 ± 0.07a              | 2.16 ± 0.52abc            |

was recorded in Isan (3.52±0.71), but it was not significantly different (P>0.05) from the weight reduction recorded in Igbemo (3.39±2.18). There was no significant difference (P>0.05) among varieties, Cisadene, Ofada and Ayede.

Means in each column bearing the same letters are not significantly different at the 5% level of probability by Tukey test.

The mean force required to crush different rice varieties is shown in Table 5. The largest force of 66.64 Newton used to crush Cisadene was significantly larger than the force required to crush all other varieties. The smallest force of 26.18 Newton was used to crush Ofada.

Means in each column bearing the same letters are not significantly different at the 5% level of probability by Tukey test.

Table 6 shows the correlations between the damage parameters and the variables assessed. Grain moisture content was significantly positively (P<0.05) correlated with number of F1 and F2 adults. It was positively correlated with percentage weight loss in grains, and negatively correlated with percentage adult mortality at week 4; but these correlations were not significant (P>0.05). There was a negative correlation between grain hardness and number of F1 and F2 adults.
Table 5 Mean force required for crushing the different rice varieties

| Rice variety       | Mean force (Newton) required to crush grains ± S.E |
|--------------------|-----------------------------------------------|
| Imported           |                                               |
| Cisadene           | 66.64 ± 6.52c                                 |
| Caprice            | 59.50 ± 11.90bc                               |
| Improved           |                                               |
| ITA 257/Faro 45    | 54.74 ± 10.64bc                               |
| ITA 315/Faro 49    | 52.36 ± 6.52bc                                |
| ITA 222/ Faro 36   | 59.50 ± 16.83bc                               |
| Local              |                                               |
| Isan rice          | 54.74 ± 10.64bc                               |
| Igbemo rice        | 38.08 ± 9.96ab                                |
| Ofada rice         | 26.18 ± 15.52a                                |
| Erio rice          | 40.46 ± 15.97ab                                |
| Ayede Ekiti rice   | 40.46 ± 10.64ab                               |

Table 6 Correlations among parameters assessed in the comparison of different varieties of rice for susceptibility to *S. oryzae*

| Parameters | Number of F1 adults | Number of F2 adults | % weight loss in grains | % mortality at 4 weeks |
|------------|---------------------|---------------------|-------------------------|-----------------------|
| Grain hardness | -0.405             | -0.530              | -0.289                  | 0.390                 |
| Moisture content | 0.961*             | 0.980*              | 0.259                   | -0.254                |
| Tannic acid    | 0.150               | 0.070               |                          |                       |
| Phenol         | 0.095               | 0.038               |                          |                       |
| Phytate        | -0.050              | 0.132               |                          |                       |
| Oxylate        | -0.335              | -0.387              |                          |                       |
| Chlorogenic acid | -0.096             | -0.147              |                          |                       |

Note: * P > 0.05

and percentage weight loss in grains. Grain hardness was positively correlated with percentage adult mortality at week 4; but not significant (P<0.05).

The number of F1 and F2 adults was also correlated with each of the anti-nutrients; the Oxylate and Chlorogenic acid content was negatively correlated with F1 and F2 adult emergence (Table 7). Phenol and Tannic acid content was positively correlated with F1 and F2 adult emergence; but not significant (P<0.05) (Table 8). Number of F1 adults was positively correlated with percentage weight loss in grains, while there was a positive correlation between number of F2 adults and percentage weight loss in grains.

3 Discussion

The damage variables used in this study to compare the susceptibilities of the different rice varieties to *S. oryzae* revealed significant differences among them. Susceptibility, which is an indication of the potential rate of increase of a pest population, was evaluated for the rice weevil in this study on the basis of F1 and F2 adult emergence, adult mortality rate, final weight loss and the index of susceptibility.

Higher mortality of introduced adults *S. oryzae* was recorded in the following varieties; Caprice, ITA 315, Cisadene, ITA257 and ITA 222. At 4 WPI, 95.0% mortality was recorded in ITA 315, 92.5% in Caprice and 85.0% in ITA 257. Lower adult mortality rate was recorded in the local varieties; 15.0% was recorded in Isan rice, which is the lowest mortality rate recorded among the ten varieties and 25.0% was recorded in Igbemo rice. The difference in the mortality between the imported and local varieties was probably due to the inability of the adults to feed on the imported varieties, since fewer F1 individuals were produced in
Relative Susceptibility and Proximate Composition of Rice Varieties by *Sitophilus oryzae* L.

Table 7 Proximate composition of the selected rice varieties used in the experiment

| Variety       | % Ash | % MC | % CP | % Fat | % Fibre | % CHO |
|---------------|-------|------|------|-------|---------|-------|
| Imported      |       |      |      |       |         |       |
| Cisadene      | 0.57  | 9.69 | 8.25 | 0.16  | 0.23    | 80.93 |
| Caprice       | 0.58  | 9.79 | 7.11 | 0.14  | 0.22    | 82.07 |
| Improved      |       |      |      |       |         |       |
| ITA257/Faro 45| 0.59  | 9.17 | 8.30 | 2.21  | 0.31    | 78.69 |
| ITA 315/Faro 49| 0.61  | 9.76 | 8.25 | 2.20  | 0.30    | 78.77 |
| ITA 222/ Faro 36| 0.60 | 9.89 | 8.34 | 2.25  | 0.32    | 78.56 |
| Local         |       |      |      |       |         |       |
| Isan Rice     | 0.63  | 11.06| 7.20 | 0.16  | 0.33    | 81.65 |
| Igbemo Rice   | 0.65  | 10.71| 8.46 | 0.18  | 0.35    | 80.15 |
| Ofada Rice    | 0.58  | 11.28| 8.42 | 0.13  | 0.34    | 79.21 |
| Erio Rice     | 0.60  | 11.54| 7.33 | 0.15  | 0.25    | 81.03 |
| Ayede Ekiti Rice| 0.63 | 11.57| 7.28 | 0.14  | 0.24    | 80.35 |

Table 8 Anti nutrients composition of the selected rice varieties used in the experiment

| Variety       | Tannic acid (mg/100g) | Phenol (mg/100g) | Phytate (mg/g) | Oxylate (mg/g) | Chlorogenic acid (g/100g) |
|---------------|-----------------------|------------------|----------------|----------------|--------------------------|
| Imported      |                       |                  |                |                |                          |
| Cisadene      | 2.07                  | 2.35             | 10.71          | 0.36           | 2.62                     |
| Caprice       | 2.72                  | 3.16             | 12.36          | 0.27           | 3.51                     |
| Improved      |                       |                  |                |                |                          |
| ITA257/Faro 45| 2.27                  | 2.68             | 8.24           | 0.27           | 2.97                     |
| ITA 315/Faro 49| 2.64                 | 2.72             | 7.42           | 0.36           | 3.02                     |
| ITA 222/ Faro 36| 2.57               | 2.76             | 10.71          | 0.63           | 3.06                     |
| Local         |                       |                  |                |                |                          |
| Isan rice     | 2.11                  | 2.31             | 11.54          | 0.27           | 2.57                     |
| Igbemo rice   | 2.92                  | 3.00             | 8.24           | 0.35           | 3.34                     |
| Ofada rice    | 2.23                  | 2.47             | 9.06           | 0.27           | 2.79                     |
| Erio rice     | 4.30                  | 4.34             | 8.24           | 0.45           | 3.74                     |
| Ayede Ekiti Rice| 2.31               | 2.51             | 8.24           | 0.27           | 2.83                     |

these varieties. In some other varieties such as; Cisadene, ITA 257 and Caprice, high adult mortality and presumably reduced oviposition may have contributed to the relatively lower F1 adult emergence from them. Consequently, those varieties in which *S. oryzae* adult survival was significantly poorer and resulting presumably to reduced oviposition manifested lower grain weight loss.

Among the explanatory variables; moisture content, anti-nutrient content and hardness used to determine the quality of various rice varieties, only moisture content appears an important variable that can be used as an indicator of resistance, since the grain moisture content was significantly positively correlated with both F1 and F2 adults. The imported varieties which recorded higher resistance had lower moisture content compared to the local varieties such as Isan, Ayede, Igbemo and Ofada varieties. This confirms the findings of Okiwelu et al. (1998) who found a significant positive correlation between moisture content and the degree of infestation. IITA (1991) indicated that, high temperature (25-30°C) and relative humidity (70%~80%) are optimum conditions for the development of storage pests such as *Sitophilus* species while low moisture content (10% or less) and low temperature (below 15°C) prevent weevil development. Ernest (1987) reported that the rate of multiplication of the insect depends upon the temperature and moisture content and upon the suitability of the grains for the reproduction of the
insect. Urrelo and Wright (1989) also reported the influence of moisture content and other factors such as; seed species, variety, age, temperature and relative humidity on *Sitophilus* oviposition.

A clear effect of grain hardness on the susceptibility of rice varieties was not observed, as there was lack of significant correlation between grain hardness and all the damage parameters assessed, as grain hardness was negatively correlated with number of F1 adults, number of F2 adults and percentage weight loss in grain. Moreover, some varieties that manifested high susceptibility possess grains which required larger force to crush them. For instance, Isan varieties which are the most susceptible out of the ten tested varieties required a similar force as ITA 257; which is less susceptible. Isan required a force larger than ITA 315; which is the most resistant variety. This study corroborate the previous study of Gudrups et al. (2001) who compared some varieties of maize for their comparative susceptibility to *S. zeamais*; he was unable to establish a clear influence of kernel hardness on the susceptibility of maize grains screened for resistance to infestation of *S. zeamais*.

Previous researches carried out by some workers to compare susceptibility among rice varieties have reported a relationship between susceptibility to *S. oryzae* and grain hardness. Enobakhare and Wey (1996) suggested that thickness of the grains have a huge influence on the resistance of rice varieties to *S. oryzae*. McGaughhey et al. (1990) found that hardness can strongly influence the ability of *S. oryzae* to reproduce in stored cereal. It was reported that physical factors such as seed or grain hardness are responsible for larval development and damage in grain. It was suggested that, the harder the grain, the fewer the eggs deposited.

However, some other workers also found a relationship between susceptibility and grain hardness. Throne et al. (2000) also suggested that kernel hardness in grains has been associated with tolerance or resistance to stored-product insects. It was concluded that, in general, progeny production decreases as kernel hardness increases. The role of grain pericarp layers on the development of *Sitophilus* species was studied by Haryadi and Fleurat-Lessard (1994). It was observed that development period of the rice weevil on polished rice was significantly longer.

Anti-nutrients content concentration in the selected varieties was examined as indicator of resistance to *S. oryzae* damage. The influence of anti-nutrients on resistance could not be established as some of the anti-nutrients correlated negatively with the number of adult emergence; except for Phenol and Tannic acid contents. Previous researches from various authors have established that factors of resistance could be the essential nutrients which may have low or no growth inhibitors, these nutrients probably favour rapid development of the weevils as suggested by Xin et al. (2012) that rice plants produce chemical defenses that prevents pest attacks.

From the parameters considered in this study, Isan rice was the most susceptible variety because it has the highest mean F1 adult emergence (70%), lowest mortality rate at 4 WPI (15.0%) and highest percentage weight loss which increased with weeks of infestation. While the least susceptible variety was ITA 315; with the highest insect mortality rate (95.0%), lowest mean F1 adult emergence and F2 adult emergence and lowest percentage weight loss (1.16%) at week 8 and (2.65%) at week 12.

According to Ashamo (2005) varieties that suffered less than 0.5% loss were considered to be resistant, 0.6 to 1% moderately resistant, 1.1 to 5.0% tolerant, 5.1 to 20.0% susceptible, and more than 20% highly susceptible. Therefore, ITA 315, ITA 257 and ITA 222 were seen to be tolerant; with ITA 315 as the most tolerant. Other varieties were susceptible. Isan rice was the most susceptible, as it recorded the highest weight loss of 17.59%, 12 WPI.

In terms of index of susceptibility, ITA 315 with index of susceptibility SI 5.4 was the most resistant (least susceptible) while Isan rice with SI 8.4 was the most susceptible (Table 9).

Generally, improved and imported rice varieties, ITA 222, Caprice, ITA 257 and Cisadene had indices of susceptibility 5.9, 6.3, 6.4 and 6.5 respectively which made them more resistant (less susceptible) than some
Table 9 Indices of susceptibility and moisture content of different varieties of rice due to *S. oryzae* infestation

| Variety       | Indices of susceptibility (S.I) | Moisture content |
|---------------|--------------------------------|------------------|
| Imported      |                                |                  |
| Cisadene      | 6.5                            | 9.86             |
| Caprice       | 6.3                            | 9.88             |
| Improved      |                                |                  |
| ITA257/Faro 45| 6.4                            | 9.90             |
| ITA 315/Faro 49| 5.4                          | 9.87             |
| ITA 222/ Faro 36| 5.9                        | 9.93             |
| Isan rice     | 8.4                            | 10.03            |
| Igbemo rice   | 7.5                            | 10.21            |
| Ofada rice    | 7.4                            | 11.32            |
| Erio rice     | 8.0                            | 10.64            |
| Ayede Ekiti rice| 8.2                         | 11.36            |

of the local varieties, Ofada, Igbemo, Erio and Ayede; with indices of susceptibility 7.4, 7.5, 8.0, and 8.2 respectively.

4 Conclusions

From the results of this research, it was observed that moisture content is a good indicator of susceptibility; while, grain hardness and anti-nutrient composition were not good indicators of susceptibility of rice varieties to *S. oryzae* infestation and damage. Also significant varietal differences exist in the susceptibility to *S. oryzae* with the improved and imported varieties exhibiting low susceptibility to infestation and damage of *S. oryzae*, compared to the locally produced varieties. The moisture content of rice grains prepared for storage should be reduced prior to storage in other to minimize post-harvest losses as a result of infestation and damage by *S. oryzae*. In lieu of the poor resistance of the locally produced varieties determined in this study, it is recommended that local rice varieties in Nigeria be tested for susceptibility to determine their qualities.

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