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Susceptibility level of some Nigerian hybrid and local rice varieties to *Sitophilus oryzae* L. (Coleoptera: Curculionidae)

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Abstract
Seven rice varieties, *Oryza sativa* (Linnaeus), [two local Nigerian varieties namely: *Igbimo* and *Ofada*; four hybrid varieties viz: ITA 321, FARO 44, WAB 189 and WITA 4; and *Aroso* (Thailand imported rice)] were screened for their susceptibility to *Sitophilus oryzae* at ambient temperature of 28±2 °C and 70–81% relative humidity in the laboratory. Ten grammes of each rice variety were infested with eight female and four male weevils and then replicated three times with the forth uninfested replicate serving as control. The least susceptible variety with the least susceptibility index (2.2) and lowest number of adult emergence (2.00) was WAB 189 while the most susceptible with the highest susceptibility index (6.0) was *Ofada.* The highest adult emergence (25.33) and percentage weight loss was recorded in *Igbimo* while the shortest developmental period (31 days) and the longest developmental period (35 days) were observed in *Ofada* and ITA 321 respectively.

Keywords: *Sitophilus oryzae*, rice varieties, *Igbimo*, *Ofada*, adult emergence.

1. Introduction
Rice, *Oryza sativa* (Linnaeus), is a crop of global importance and it is one of the most important cereal grains which has contributed over 60% of the total world food production. Only 5% of the rice grown is used as processed foods, industrial products or alcoholic beverages, humans consume 95% as an unprocessed food [1]. It is the main staple food for half to two-third of the world population particularly the Asian Continent where it accounts for more than half of the daily calorie intake [2]. Among important starchy foods in West African countries including Nigeria, the demand for rice has surpassed maize, yam and cassava [3]. In Nigeria, as people's income increases, many shifted their consumption behaviour in preference of well-cultivated rice variety.

Rice shows more genetic and morphological diversity than many other cultivated crops, the extent of variation in its morphology and physiological features are greater than any other cereal [4, 5]. Based on qualitative characters of the endosperm, rice variety may glutinous or opaque and non-glutinous or translucent while on grain length there is long, medium and short type [6]. Some local varieties such as *Igbimo*, *Ofada* and *Abakaliki* as well as some other improved (hybrids) varieties like WITA, Cisadene, ITA 150, ITA 257, ITA 321 etc are cultivated in Nigeria. Presently there is an increase in the cultivation of rice across the nation with increased access to production inputs [7].

Insects, especially rice weevil, *Sitophilus oryzae* Linnaeus, which is a primary pest of rice causes extensive damage to the harvested rice grains in storage resulting in about 20-40% weight loss [8]. Most of the damage to rice grain is done by the larvae which devour almost the whole endosperm leaving only the hull [9]. Resistance to attack by insects during storage (that is, varietal resistance) is generally being explored as one of the alternatives to the use of synthetic insecticides. Previously, the acreage planted with rice varieties resistant to insects (mainly field pests) represents only a small fraction of the total rice production [10], but presently this has changed and new rice varieties have resulted in dramatic increase in yield. Some researches have been carried out on varietal resistance of rice to *S. oryzae* [11-14], but several hybrid varieties are yet to be tested for postharvest pest susceptibility due to the continuous release of new hybrids. Hence, this study screened and compared four hybrid rice varieties from the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria; two local (unhybridized) varieties and one exotic variety for susceptibility to *S. oryzae*.

2. Materials and method
2.1 Insect culture and maintenance
The *S. oryzae* (L.) used for this study was obtained from stock culture in the Storage Research Laboratory of the Federal University of Technology Akure, Nigeria. New generations were reared on clean and uninfested polished Thailand rice variety (locally called *Aroso* in Nigeria) in 1-litre Kilner jars covered with muslin cloths to ensure ventilation and prevention of weevil escape or entrance of other insects. This culture was maintained at a temperature of 28±2 °C and relative humidity range between 70-81%. The above temperature and relative humidity were used throughout the course of the experiment in the above laboratory.

2.2 Sourcing of rice varieties
Seven varieties of rice grains were tested in this study. Four hybrids (locally improved varieties) were obtained from the International Institute of Tropical Agriculture (IITA) Ibadan, Nigeria and were dehulled. These varieties are: FARO 44, WAB 189, WITA 4 and ITA 321. Two local varieties, *Igbimo* and *Ofada* and one "exotic" polished Thailand rice variety (locally called "*Aroso*") were obtained from Oba market in Akure, Ondo State, Nigeria. The morphological characteristics of these rice varieties are shown in Table 1.

2.3 Assessment method

At the start of the experiment, the initial moisture content of each rice variety was determined using Mettler LJ16 Moisture Analyser at 105 °C for 15 minutes. Likewise, the final moisture content of the varieties was taken at the end of the experiment (Table 2).

Ten grammes of each rice variety were weighed separately into four plastic Petri-dishes. The fourth replicate served as control without weevil infestation for each variety. Newly emerged *S. oryzae* were differentiated into sexes using the method of Grist and Lever [15], thereafter eight females and four males were introduced into each dish. Holes were made on the Petri-dish lids and then covered with muslin cloth to allow ventilation, and also to prevent the weevils from escaping. The infested rice varieties were left for two weeks before the removal of the adult weevils. After another two weeks when the F_1 generation started emerging, the samples were inspected daily and newly emerged adult *S. oryzae* were counted, recorded and removed. Data collection for each sample was for a period of three weeks from the date of first emergence of adult to avoid interference with F_2 generation. At the end of the experiment, the weight of the various rice samples was taken.

The percentage weight loss was calculated thus: the difference between the initial and final weight of the control was deducted from the difference between the initial and final weight of the infested grains in each variety. This value represents the loss in weight caused by weevil feeding activity. Any difference in weight of the control was assumed to be due to moisture changes only.

Actual weight loss (W) = (X – CF) – Y

Where, X = Initial weight of uninfested rice sample

Y = Final weight of infested rice sample

CF = Weight loss in the control assumed to be due to moisture loss

$$\text{Percentage weight loss} = \frac{W}{X} \times \frac{100}{1}$$

Susceptibility is an indication of the potential rate of increase of a pest population. The index of susceptibility (SI) for each rice variety was calculated as described by Dobie [16]. This was determined as follows:

$$\text{Index of susceptibility} = \frac{\text{Natural Log F}}{D} \times \frac{100}{1}$$

Where F = Total number of emerged F_1 adult insects

D = 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 F_1 generation [16].

2.4 Data analysis

All the data obtained were subjected to analysis of variance (ANOVA) and where significant differences occur, the means were separated using Duncan's New Multiple Range Test.

3. Results

Table 1 shows the length of the local varieties to be between 0.60-0.69cm while the hybridized ones are have lengths ranging between 0.65-0.79cm. Only variety WAB 189 have a shiny colouration like the imported variety, the Nigerian varieties (both local and hybridized) are mostly dull. Table 2 shows a general increase in the moisture content of the rice varieties (except the imported variety) infested with *S. oryzae* with a range of 2.99-4.67% and 4.31-6.17% before and after infestation respectively. However, less than 40% increment was observed in the local varieties while the hybrid varieties have more than 40% moisture increment with the exception of WAB 189 (28.13 % increase). ITA 321 had the highest moisture increase (about 85%).

The mean number of *S. oryzae* that emerged from the different varieties varied significantly. Table 3 shows that significantly higher numbers of progeny were produced in the two unhybridized local varieties, *Igbimo* and *Ofada*, with adult emergence of 25.33 and 24.33 respectively. The lowest number of emergence (2.0) was recorded in WAB 189. Emergence from varieties WAB 189, FARO 44, ITA 321 and WITA 4 were not significantly different (P>0.05) from each other, although ITA 321 had the highest emergence of 12.66 out of all these improved varieties. The result (Table 3) also shows that the imported variety (*Aroso*) had slightly higher number of adult emergence than three of the locally improved varieties, viz, FARO 44, ITA 321 and WITA 4 but this was not significantly different from those of all the four improved varieties. The above result showed that all the improved varieties investigated are more resistant to rice weevil attack and proliferation than the local ones. It also revealed that WAB 189 is the most resistant of all the improved varieties investigated, even more resistant than the imported variety tested. Likewise, *Igbimo* variety is slightly more susceptible to weevil attack than *Ofada.*

Table 3 also shows that all the varieties lost weight due to the feeding activity of *S. oryzae*, but the two unhybridized local varieties had significantly higher weight loss than the other varieties. *Ofada* suffered the highest loss in weight (0.93%) which was significantly higher than that of *Igbimo* (0.60%). The lowest weight loss of 0.06% was recorded in FARO 44, WITA 4 and *Aroso*. ITA 321 suffered the highest weight loss (0.20%) out of all the improved varieties but this was not significantly different from that of the others and *Aroso*.

Figure 1 shows that the developmental period of *S. oryzae* was longest in ITA 321 (35 days) and shortest in *Ofada* (31 days). It also shows the index of susceptibility of the different varieties of rice to *S. oryzae*. The local varieties (*Igbimo* and *Ofada*) have higher index of susceptibility than the others, hence they are less resistant to *S. oryzae* infestation. *Ofada* was the most susceptible of all the varieties with a SI of 6.0, followed by *Igbimo* (SI=5.5). The variety with the lowest index of susceptibility (SI) was WAB 189 with SI 2.2, this therefore was the least susceptible (most resistant) of all the varieties investigated. The most susceptible of the improved varieties is ITA 321 which had the highest SI (4.5) out of the four.

Table 1: Morphological Characteristics of the Experimental Rice Varieties

Variety	Colour	Grain length (cm)	Shape	Appearance	Cultivated habitat
Igbimo	Dull white	0.60cm	Long/fairly robust	Opaque	Upland
Ofada	Dull white	0.69cm	Long/fairly robust	Opaque	Upland
FARO 44	Dirty white	0.70cm	Long/slender	Opaque	Lowland
WAB 189	Shiny brown	0.79cm	Long/robust	Opaque	Upland
WITA 4	Dull cream	0.70 cm	Long/slender	Opaque	Lowland
ITA 321	Dull brown	0.65cm	Long/fairly robust	Opaque	Upland
Aroso	Shiny cream	0.70cm	Long/slender	Translucent	Lowland

Table 2: Moisture content of rice varieties before and after 7 weeks of infestation with *Sitophilus oryzae* at 28 ± 2 °C and 75 ± 5% R.H.

Variety	Initial Moisture Content (%)	Final Moisture Content (%)	Moisture Increase (%)
Igbimo	4.67	6.17	32.12
Ofada	3.49	4.80	37.54
FARO 44	3.61	6.05	67.59
WAB 189	4.80	6.15	28.13
WITA 4	2.99	4.33	44.82
ITA 321	3.21	5.93	84.73
Aroso	4.31	4.31	0.00

Table 3: Adult Emergence of *Sitophilus oryzae* and percentage weight loss of rice varieties after 7 weeks of infestation at 28 ± 2 °C and 70 - 81% R.H.

Variety	Number of adult emergence (Mean ± S.D.)	%Weight Loss (Mean ± S.D.)
Igbimo	25.33 ± 7.23^{b}	0.60 ± 0.17^{b}
Ofada	24.33 ± 10.21^{b}	$0 .20 \pm 0.10^{a}$
FARO 44	3.00 ± 3.60^{a}	0.06 ± 0.05^{a}
WAB 189	2.00 ± 2.64^{a}	0.16 ± 0.11^{a}
WITA 4	3.00 ± 2.00^{a}	0.06 ± 0.05^{a}
ITA 321	12.66 ± 6.42^{a}	0.93 ± 0.30^{c}
Aroso	6.66 ± 1.52^{a}	0.06 ± 0.05^{a}

Mean values in a column followed by the same letter are not significantly different (P>0.05) by Duncan's New Multiple Range Test.

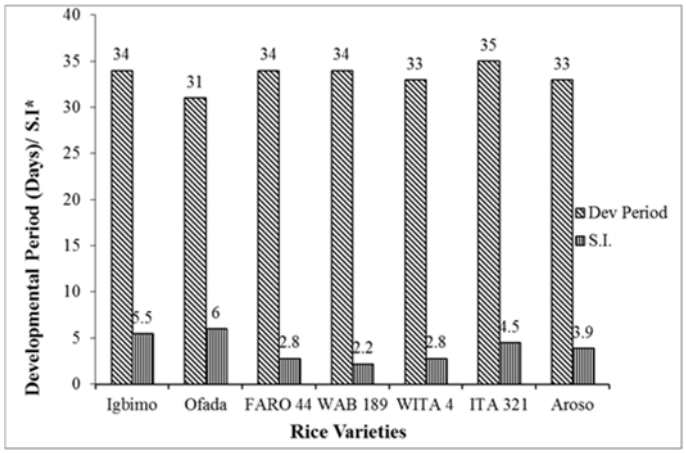

Fig 1: Developmental period of *S. oryzae* in Nigerian rice varieties and the Index of Susceptibility (S.I.) of these varieties
* S.I. has no unit

4. Discussion

The parameters considered in this study showed WAB 189 variety to be the most resistant rice variety to *S. oryzae* out of all the investigated varieties. It has the least index of susceptibility (SI 2.2) and the least F_1 adult emergence (2.00). Being the longest grain investigated (0.79cm), this is a departure from the general report by other Varietal resistance researchers who had reported a positive correlation between grain size and index of susceptibility to *Sitophilus* species [10, 13, 17]. Nevertheless, other physical factors of resistance such grain hardness and thickness could have been responsible for its low susceptibility. Grain hardness is found to be negatively correlated with susceptibility to *Sitophilus* species [9, 10, 11, 16, 17]. Although not measured in this study, the hardness of this variety might have reduced the ability of adult weevil to make hole on the grains for oviposition and likewise reduce the ability of the larvae to feed properly on the endosperm. Out of all the Nigerian varieties investigated in this study, WAB 189 had the lowest moisture increase (28%) during infestation. Harris and Lindblad [18] stated that dry conditions cause feeding, reproductive and living distress for insects. This invariably could also account for the low number of F_1 progeny that emerged from this grain.

The above reason could also be adduced to other investigated varieties such as WITA 4, FARO 44, and *Aroso* which also had low susceptibility indices (2.8 to 3.9) and adult emergence (3.00 to 6.66). The higher susceptibility and adult emergence observed in ITA 321 than the other hybrid varieties could be connected to its dull brown appearance. Throne *et al* [10] documented that weevils develop well on brown rice prepared from rough rice varieties that were resistant. ITA 321 which is the most susceptible of all the varieties investigated was also more susceptible to *S. oryzae* attack than the imported variety (*Aroso*). This was in line with the observations of Ashamo [13] who reported a higher susceptibility index than that of *Aroso* in 9 Nigerian hybridized varieties out of the 10 elite varieties he investigated. However, this study showed that some of Nigerian hybridized varieties can now compete favourably with the imported ones in storage on the basis of resistance to rice weevil attack and the post harvest weight loss associated with such attack.

The local unhybridized rice varieties used in this study were more susceptible to *S. oryzae* attack than the imported and elite varieties as shown by their higher SI and adult emergence. This could be due to their reduced hardness and high nutrient quality. The process of dehulling and high-tech polishing reduces the nutrient of rice grain, especially the vitamins. The unhybridized local varieties have limited processing and are seldom polished, therefore there is the tendency of having higher nutritional value than the highly polished imported and some elite varieties. In actual fact, some Nigerians prefer the local unhybridized varieties to the imported/hybridized varieties with claims that they (unhybridized) are more nutritious, starchy and delicious. The high adult emergence observed from the unhybridized varieties could be as a result of the availability of nutritional requirement that support the population growth of *S. oryzae*. Population growth of *S. oryzae* is known to be influenced by the medium in which the insect is reared [19]. Other factors of resistance could be essential nutrients which may have low or no growth inhibitors that could favour the rapid development of the

weevils [19, 20]. High amylase content favoured the development of *S. zeamais* [10], this reason could account for the lowest developmental time of 31days observed in *Ofada*.

On the basis of weight loss suffered due to action of *S. oryzae* feeding activities, a 9-point scale used for categorizing the extent of losses [21] considered all the elite varieties investigated and the imported variety (*Aroso*) to be resistant because they suffered less than 0.5% loss in weight. The scale considered varieties that suffered less than 0.5% loss to be resistant (ranked 1); 0.6 to 1% moderately resistant (ranked 3); 1.1 to 5% tolerant (ranked 5); 5.1 to 20% susceptible (ranked 7); and more than 20% highly susceptible (ranked 9). This implies that *Igbimo* and *Ofada* could be considered to be moderately resistant because their percentage weight loss were 0.6% and 0.93% respectively.

The indices of susceptibility (SI) observed in this work is much lower than those of Ashamo [13]. The SI ranged from 2.2 to 6.0 while that of Ashamo [13] ranged from 5.5 to 10.8. The initial moisture content of the varieties used in this work (2.99% to 4.80%) was lower than those used by Ashamo [13] (4.87% to 6.90%). These lower moisture contents might have affected the initial availability of moisture for the development of the weevil and the subsequent adult emergence which will in turn reduce the SI. Lower moisture content will increase grain hardness, therefore dehulled rice should be kept at lower moisture level during storage. It is even better to store un-dehulled rice for long-term storage because the intactness of the hull is one of the major factors that confer resistance on rice grains against rice weevil attack [12, 14, 22].

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