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Role of Physical Characteristics of the Seed on the Stability of Resistance of Maize Varieties to Maize Weevil (Sitophilus Zeamais Motschulsky)

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Abstract: *Eighteen maize varieties were evaluated in this study of the role of physical characteristics of the grain on the stability of resistance of maize varieties to maize weevil Sitophilus zeamais Motschulsky. Fifteen hybrids (TZLCOMP3C3F2, AflatoxinSynW4, Obatanpa/TZL COMP4C3, Syn/Clfo/Obatanpa TZL COMP3*2, Obatanpa/IWDC2 SYN, Obatanpa/TZLCOMP3C3, Aflatoxin Syn W3, TZB-SR, TZL COMP4C4 F2, ACR 06 TZL COMP4 C4 F2, TZL COMP3 C3 DT, ACR O6TZL COMP3 C4 F2, TZL COMP4 C3 F2, TZL COMP4 C3 DT, Aflatoxin Syn3-W) obtained from the Maize Programme Unit, International Institute for Tropical Agriculture (IITA) Ibadan, Nigeria and three local cultivars (Akparike, Bende and Ogbia muno) of maize were screened over four successive generations under laboratory conditions (25-320C and 55-85% r.h). Grain size, kernel hardness, grain weight loss, and the number and mortality of adult progeny over four successive generations were recorded and used to determine the stability of resistance of the maize varieties to S. zeamais. Mean numbers of adults that developed from 10g of the 18 varieties differed significantly ($P \leq 0.05$) and ranged from 0.13 for the improved variety TZL COMP3 C3 DT to 26.00 in the local cultivar Bende. The results indicated that the improved varieties produced fewer S. zeamais adult progeny while the local cultivars supported larger populations. The variety TZLCOMP3C3DT showed absolute immunity to S. zeamais infestation with 100% mortality and no sign of grain damage in the third and fourth generations of infestation. Over four successive generations, the general trend observed was a decline in S. zeamais adult progeny which may be attributed to the physical properties of the maize varieties as well as chemical properties such as the presence of soluble phenolics. Using improved maize varieties as this study shows is a possible tool for insect pest control especially perhaps if utilized in combination with other control methods.*
Key words: *Sitophilus zeamais; stability; generations; food security; pest*

I. Introduction

Maize or corn is a cereal crop that is grown widely throughout the world in a range of agroecological environments. Maize, Zea mays L. is a major component in the diet of the people of sub-Saharan Africa. According to Siwale et al., 2009, it is the third most produced cereal after wheat and rice in the world; also the third most important cereal crop grown in Nigeria, next only to sorghum and millet (Adedire et al., 2011). Maize is an important subsistence and cash crop in Nigeria, with an estimated national production of 5.2 million metric tons (Issa et al., 2011). About 50 species exist and consist of different colours, textures and grain shapes and sizes. White, yellow and red are the most common types. The white and yellow varieties are preferred by most people depending on the region.

Maize is often heavily infested in the tropics by various vertebrate and invertebrate pests which include rodents and insects, the most important of these being the maize weevil, Sitophilus zeamais Motschulsky (Adedire et al., 2011). The maize weevil is a major primary, field –to- store pest of maize in tropical storage (Haines, 1991). Infestation usually starts in the field and is later carried into the grain stores where up to 30-50% of the grain is damaged after six months' storage (Giles, 1969; Haines, 1991). Post- harvest losses to storage pests such as S.zeamais have been seen as an increasingly important problem in Africa and other tropical countries (Abebe et al., 2009). Damaged grains have reduced nutritional values, impaired germinability, reduced weight and market values (Abebe et al., 2009). Losses ranging from 20 to 90% due to S. zeamais infestation in unprotected maize grains have been reported (Adedire et al., 2011).

The devastating loss of stored products to insect attack has therefore necessitated the use of various measures to control maize weevils. Methods employed in pest control include the use of botanicals, biological control, cultural control, hermetic storage, controlled atmosphere and chemical methods (Umeozor, 2009). Following the widespread use of insecticides for the control of stored product insect pests, a global concern with respect to environmental harzards, insecticide resistance development, chemical residues in food, side effects on non-target organisms and the associated high cost, alternative methods of control have been canvassed. Consequently, the use of resistant maize cultivars against S. zeamais has been promoted.

Maize cultivars differ in their resistance to S. zeamais infestation. Physical characteristics of the seed such as colour, kernel harness, testa thickness and seed size amongst others are known to influence the resistance of cereal cultivars to infestation by species of Sitophilus (Ivbijaro, 1981; Ashamo, 2001). However, the use of less susceptible maize cultivars, in conjunction with other control methods to form an integrated pest management (IPM) programme may provide a more efficient system to maintain insect population in stored maize at an acceptable level in the tropics. There is also a report of increased susceptibility of varieties of crops to store product insects (Adedire et al., 2011). It is therefore pertinent to routinely screen new crop varieties for resistance to insect pests of stored products. It is against this background that this study sought to assess the stability of resistance offifteen improved maize varieties to S. zeamais infestation.

II. Materials And Method

Experimental Site

The experiment was carried out in the Entomology Research Laboratory of the Department of Animal and Environmental Biology, University of Port Harcourt. The experiment was carried out in different phases.

Maize varieties

The eighteen maize varieties comprising fifteen hybrids (TZLCOMP3C3F2, AflatoxinSynW4, Obatanpa/TZL COMP4C3, Syn/Clfo/Obatanpa TZL COMP3*2, Obatanpa/IWDC2 SYN, Obatanpa/TZLCOMP3C3, Aflatoxin Syn W3, TZB-SR, TZL COMP4 C4 F2, ACR 06 TZL COMP4 C4 F2, TZL COMP3 C3 DT, ACR O6TZL COMP3 C4 F2, TZL COMP4 C3 F2, TZL COMP4 C3 DT, Aflatoxin Syn3-W) and three local cultivars (Akparike, Bende and Ogbia muno) that are normally grown by local farmers in the Niger Delta region were screened. The fifteen hybrid varieties were obtained from the Maize Programme, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria while the three local cultivars were purchased from open markets in Choba and Emohua both in Rivers State, Nigeria.

Insect Culture

Adults of S. zeamais were collected from infested maize bought from two local markets in Rivers State (Choba market and Oil mill market) and from the stock culture reared at the Department of Crop and Soil Science, Faculty of Agriculture, University of Port Harcourt. These insects have been maintained on whole maize without exposure to insecticides. Maize sample of local white variety (Coma) was obtained from Choba market, Choba, Rivers State and disinfected for 72 hours in a deep freezer. The maize sample was put into a 10 litre kilner glass jar and adult S.zeamais was introduced. The container was covered with muslin cloth held in place by rubber band to allow adequate aeration and prevent escape of weevil or entry of predatory ants. All adult weevils were removed after seven days by sieving and the culture was kept at 25-32^{0}C and 55-85% r.h for adult emergence. Emerged adult weevils were used for the study.

Experimental Procedure

Morphological characteristics of the grains

The physical characteristics of the maize varieties measured were colour, length, breadth and width. The colours were observed visually, while the length and width of the grains of each of the sampled maize cultivar were measured using a measuring ruler. The weight was taken on a sensitive Mettler balance (A &D Electronic balance FX-6000).

Grain hardness test

Grain hardness was determined using CBR Compression machine with a maximum load of 600kg in the Department of Applied Geology, Federal University of Technology, Akure, Nigeria. Ten grains were randomly selected from each of the variety/cultivar and tested for hardness. Each grain was carefully placed in a vertical position on the stage meter and crushed. The hardness of the grain was obtained by multiplying the value obtained at the point when the grain cracked by a factor (23.8N/div).

Susceptibility of varieties to Sitophilus zeamais

Ten grams of each maize variety was weighed into kilner jars and 10 pairs of adult S.zeamais were introduced into each container. The container was covered with muslin cloth for aeration. This was replicated four times. The insects were sexed using the methods of Halstead (1963). Males were recognized by their short and broad rostrum, but long and narrow for the females. The infested maize was left for 7 days in a rodent-proof wooden cage in the laboratory during which the insects fed and laid eggs. On the 7th day after infestation, adult weevils were removed. The total number of eggs laid were counted and recorded.

Egg plug determination (oviposition rate)

Egg plugs were identified according to the procedures of Frankenfeld (1948) using acid fuschin dye. Acid fuschin dye solution was prepared using 0.5g acid fuschin added to a mixture of 50ml of glacial acetic acid and 950ml distilled water. Five grains were taken randomly from each replicate and soaked in warm water (about 50^0-60^0C) for 5 minutes. The water was drained off and the grains were soaked with acid fuschin solution for 2 minutes. The dye solution was poured out and the grains were washed in the tap to remove excess dye. The grains were left for 2 minutes after which they were examined under a dissecting microscope to locate the gelatinous egg plugs which stained cherry red. It was assumed that each egg plug covered only one egg and each egg was covered by one plug and each plug was covered by one plug. Feeding puncture and mechanical injuries were distinguished from the gelatinous egg plug by their shiny surfaces.

Stability of resistance eighteen maize varieties to S. zeamais infestation in four successive generations.

The eighteen maize varieties were screened against S. zeamais to evaluate their level of stability under laboratory conditions .Temperature and humidity readings were recorded throughout the duration of the work using a mini- hygrothermograph (Micro two-cylinders 597211). The experimental jars and maize varieties were all sterilized thermally in a hot-air Gallenkamp oven at 60^0C for 2 hours to kill any pest and pathogen that might be present and allowed to acclimatize for 24 hours to laboratory temperature (30^0C) in the laboratory.

Ten pairs of 1-7 day old adult S. zeamais were introduced into separate jars containing 10g each of maize variety weighed on a sensitive Mettler Balance (A&D Electronic Balance FX-6000) and left for seven days to oviposit. Each variety had four replicates in a completely randomized design (CRD) and they were kept in a caged box. On the seventh day, the adults were removed by emptying the contents of each jar on a piece of white paper and adults were removed using a soft entomological brush. Subsequently, the content of each jar was carefully returned into the jar and kept in its original position in the shelf and left undisturbed for 40 days to enable the insects to complete their development. The adult progeny that developed in the F_1 generation were counted and used to infest fresh 10g lots of maize grains for the F_2 generation. Similarly, adult progeny from the F_2 generation were used to establish the experiment in the F_3 generation and F_3 adult progeny for F_4 generation.

Adult progeny that emerged after 40 days of infestation and dead weevils were counted at the end of each generation (40 days after infestation) For each generation, the grains were weighed and counted before infestation and after 40 days following the removal of a generation of insects. Seed weight loss was determined using the count and weight method of Gwinner et al. (1996). Numbers of damaged and undamaged grains were recorded.

Weight loss (%) = (Wu x Nd) - (Wd x Nu) X 100 / Wu x (Nd + Nu)

Where Wu = Weight of undamaged seed, Nu = Number of undamagedseed,

Wd = Weight of damaged seed, and Nd = Number of damaged seed

Analytical procedure: Data collected were subjected to analysis of variance (ANOVA) for factorial experiments with maize variety and generation of adult progeny as factors. Significant differences between means were separated using Student-Newman-Keuls (SNK) test at the 5% level of probability.

III. Results

Physicalcharacteristics of maize grains as a factor affecting the stability of maize varietiesto S.zeamais infestation.

Table 1 shows grain length, width, weight and hardness of the different maize varieties. Data on mean width indicate that Ogbia Muno, a local cultivar, had the largest width which was followed by Bende another local variety and their width size was significantly different from those of the improved varieties. TZL COMP4 C3 F2, an improved variety, was the longest of all the varieties, the shortest being Akparike, a local variety. Grain hardness test indicated that varieties TZLCOMP3C3F2, TZL COMP3 C3 DT, were the hardest though they did not differ significantly from AflatoxinSynW4, Syn/Clfo/Obatanpa TZL COMP3*2, Aflatoxin Syn W3, TZB-SR, OGBIA MUNO, ACR O6TZL COMP3 C4 F2 and TZL COMP4 C3 DT in this respect. With respect to the softest kernels, hardness decreased in the order: ACR 06 TZL COMP4 C4 F2 > TZL COMP4 C4 F2 > Aflatoxin Syn3-W > Bende.

Oviposition preference of S. zeamais on different maize varieties

There were significant differences (P>_0.05) in the number of eggs oviposited by S.zeamais on the 18 varieties. ACRO 06TZL COMP4C4F2 and TZL COMP3C3DT had the least oviposition rate, both having mean values of 0.5 as seen in Table 5. BENDE had the highest rate of oviposition, having a mean value of 13.00 (Table 2).

Effect of variety on adult progeny development in successive generations.

Table 3 shows that the mean number of adults that developed in the eighteen varieties over four generations generally declined with increasing generation. The local susceptible variety, Bende followed an opposite trend having an increasing number of adult S. zeamais over the generations. Across the eighteen varieties the numbers of emerging adults were significantly different ($P \leq 0.05$) and ranged from 0.13 for the improved variety TZL COMP3 C3 DT to 26 in the local variety Bende. The number that emerged from the improved varieties varied in the increasing order: TZL COMP3 C3 DT< TZL COMP4 C4 F2< TZB-SR< ACR O6TZL COMP3 C4 F2< ACR 06 TZL COMP4 C4 F2< Aflatoxin Syn W3< AflatoxinSynW4< Obatanpa/IWDC2 SYN< Aflatoxin Syn3-W< TZLCOMP3C3F2< TZL COMP4 C3 F2< Obatanpa/TZLCOMP3C3< Obatanpa/TZL COMP4C3< Syn/Clfo/Obatanpa TZL COMP3*2.

Effect of variety on mortality of adult S. zeamais.

Table 4 shows a marked decline in mortality over four successive generations. The improved variety TZL COMP3 C3 DT had 100% mortality in the F_1 generation showing an absolute immunity to S. zeamais infestation. Across the varieties, mortality was highest in the improved variety ACR O6TZL COMP3 C4 F2; but this did not differ significantly from mortality levels in AflatoxinSynW4, Obatanpa/IWDC2 SYN, Obatanpa/TZLCOMP3C3, Aflatoxin Syn W3, TZL COMP4 C4 F2, ACR 06 TZL COMP4 C4 F2, and TZL COMP3 C3 DT. The variety with the lowest mortality was the local variety Ogbia muno, though its mean did not differ significantly from the levels in TZLCOMP3C3F2, Obatanpa/TZL COMP4C3, Syn/Clfo/Obatanpa TZL COMP3*2, TZB-SR, TZL COMP4 C3 F2, TZL COMP4 C3 DT, Aflatoxin Syn3-W and the other local varieties: Bende and Akparike.

Effect of variety on weight loss of grains.

The effect of pest activities on weight loss is shown in Table 5. The trend over successive generations showed a decline across most of the varieties. In improved varieties TZL COMP4 C4 F2 and ACR 06 TZL COMP4 C4 F2, an opposite trend was observed, weight loss increased over successive generations. In the local cultivar Bende and the improved variety TZL COMP4 C3 DT, weight loss was stable over four generations. Across the means of variety, highest weight loss was observed in the local cultivars Akparike and Bende. At the other extreme, weight loss was minimal in improved variety TZL COMP4 C4 F2, though its mean was not significantly different from those of improved varieties; TZLCOMP3C3F2, Obatanpa/IWDC2 SYN , Obatanpa/TZLCOMP3C3, Aflatoxin Syn W3, TZB-SR, ACR 06 TZL COMP4 C4 F2, TZL COMP3 C3 DT , ACR O6TZL COMP3 C4 F2 and Aflatoxin Syn3-W .

Table 1: Mean values of the physical properties of the maize varieties

Variety	Colour	Width (cm)	Length (cm)	Weight (g)	Hardness (N)
TZLCOMP3C3F2	White	$0.83{\pm}0.03^{b}$	$1.03{\pm}0.05^{ab}$	$0.27{\pm}0.02^{abc}$	$240.38{\pm}10.91^{a}$
AflatoxinSynW4	White	$0.94{\pm}0.05^{b}$	$1.05{\pm}0.05^{ab}$	$0.29{\pm}0.07^{abc}$	$183.26{\pm}12.87^{abc}$
Obatanpa/TZL COMP4C3	White	$0.96{\pm}0.02^{b}$	$1.06{\pm}0.05^{ab}$	$0.26{\pm}0.02^{abc}$	$138.04{\pm}15.38^{c}$
Syn/Clfo/Obatanpa TZL COMP3*2	White	$0.90{\pm}0.04^{b}$	$0.98{\pm}0.04^{ab}$	$0.22{\pm}0.01^{bc}$	$190.40{\pm}27.49^{abc}$
Obatanpa/IWDC2 SYN	White	$0.95{\pm}0.02^{b}$	$1.13{\pm}0.03^{ab}$	$0.32{\pm}0.06^{ab}$	$159.46{\pm}20.09^{bc}$
Obatanpa/TZLCOMP3C3	White	$0.93{\pm}0.03^{b}$	$1.01{\pm}0.04^{ab}$	$0.25{\pm}0.03^{abc}$	$166.60{\pm}26.55^{bc}$
Aflatoxin Syn W3	White	$0.89{\pm}0.03^{b}$	$1.07{\pm}0.03^{ab}$	$0.21{\pm}0.01^{c}$	$199.92{\pm}15.95^{abc}$
TZB-SR	White	$0.85{\pm}0.03^{b}$	$0.97{\pm}0.04^{ab}$	$0.23{\pm}0.02^{abc}$	$180.88{\pm}21.93^{abc}$
TZL COMP4 C4 F2	White	$0.90{\pm}0.06^{b}$	$1.12{\pm}0.05^{ab}$	$0.29{\pm}0.03^{abc}$	$147.56{\pm}11.66^{c}$
OGBIA MUNO	Yellow	$1.09{\pm}0.03^{a}$	$1.11{\pm}0.04^{ab}$	$0.34{\pm}0.03^{a}$	$180.88{\pm}16.72^{abc}$
ACR 06 TZL COMP4 C4 F2	White	$0.90{\pm}0.02^{b}$	$1.09{\pm}0.03^{ab}$	$0.24{\pm}0.02^{abc}$	$152.32{\pm}15.14^{c}$
TZL COMP3 C3 DT	White	$0.86{\pm}0.04^{b}$	$1.07{\pm}0.03^{ab}$	$0.24{\pm}0.02^{abc}$	$226.10{\pm}9.55^{ab}$
ACR O6TZL COMP3 C4 F2	White	$0.89{\pm}0.02^{b}$	$1.11{\pm}0.03^{ab}$	$0.29{\pm}0.02^{abc}$	$180.88{\pm}19.82^{abc}$
AKPARIKE	White	$0.93{\pm}0.02^{b}$	$0.96{\pm}0.04^{b}$	$0.29{\pm}0.01^{abc}$	$166.60{\pm}15.87^{bc}$
TZL COMP4 C3 F2	White	$0.94{\pm}0.03^{b}$	$1.14{\pm}0.03^{a}$	$0.30{\pm}0.03^{abc}$	$159.46{\pm}50.22^{bc}$
TZL COMP4 C3 DT	White	$0.95{\pm}0.03^{b}$	$1.13{\pm}0.04^{ab}$	$0.27{\pm}0.03^{abc}$	$180.88{\pm}16.72^{abc}$
BENDE	White	$1.07{\pm}0.03^{a}$	$1.05{\pm}0.03^{ab}$	$0.26{\pm}0.02^{abc}$	$80.92{\pm}7.27^{d}$
Aflatoxin Syn3-W	White	$0.94{\pm}0.03^{b}$	$1.03{\pm}0.02^{ab}$	$0.22{\pm}0.01^{bc}$	$126.14{\pm}13.42^{cd}$

Each value is the mean ± standard error of four replicates. Mean followed by different letter (s) in each column are significantly differentat ($P \leq 0.05$) by SNK's test.

Table 2: Oviposition of Sitophilus zeamais on eighteen maize varieties.

Variety	**Average number of eggs laid**
TZL COMP4C3F2	4.50^{c}
TZL COMP3C3DT	0.50^{de}
AKPARIKE	7.50^{b}

TZB-SR	1.00^{d}
BENDE	I3.00^{a}
ACRO 06TZL COMP4C4F2	0.50$^{d.e}$
OBATANPA/TZLCOMP4C3	6.00^{bc}
TZLCOMP4C4F2	4.25^{c}
OBATANPA/IWD C2SYN	3.25^{cd}
TZLCOMP4C3DT	6.75^{b}
AFLATOXINSYN-W4	2.25^{d}
ACRO 06TZLCOMP3C4F2	1.50^{d}
AFLATOXINSYN3-W	5.25^{bc}
SYNLDFO/OBATANPATZLCOMP3C3*2	5.00^{bc}
TZLCOMP3C3F2	3.00^{cd}
OBATANPA/TZLCOMP3C3	4.75^{c}
OGBIA MUNO	6.75^{b}
AFLATOXIN SYN-W3	5.50^{bc}

SED (0.72): Oviposition Rate: Means with the same letters are not significantly (P<_0.05) different.

Table 3: Mean number of adult Sitophilus zeamais that developed in successive generations in different varieties of maize

Variety	F_1	F_2	F_3	F_4	Variety mean
TZLCOMP3C3F2	13.75^{b}	18.75^{a}	4.75^{c}	5.50^{c}	10.69^{cde}
AflatoxinSynW4	14.50^{a}	14.00^{a}	4.00^{b}	3.75^{b}	9.06^{def}
Obatanpa/TZL COMP4C3	16.00^{b}	22.50^{a}	11.00^{c}	8.75^{c}	14.56^{bcd}
Syn/Clfo/Obatanpa TZL COMP3*2	22.50^{a}	23.25^{a}	8.25^{b}	10.75^{b}	16.19^{bc}
Obatanpa/IWDC2 SYN	15.50^{a}	13.75^{ab}	8.75^{b}	3.25^{c}	10.31^{cde}
Obatanpa/TZLCOMP3C3	18.00^{a}	20.00^{a}	8.75^{b}	11.00^{b}	14.45^{bcd}
Aflatoxin Syn W3	13.75^{a}	11.75^{a}	1.25^{b}	1.25^{b}	7.00^{efgh}
TZB-SR	6.00^{a}	1.75^{b}	0.00^{b}	0.00^{b}	1.94^{hi}
TZL COMP4 C4 F2	0.75^{a}	0.25^{a}	0.50^{a}	0.00^{a}	0.38^{i}
OGBIA MUNO	11.50^{a}	6.25^{ab}	4.25^{b}	9.50^{ab}	7.88^{efg}
ACR 06 TZL COMP4 C4 F2	8.25^{a}	7.25^{a}	0.50^{b}	0.00^{b}	4.00^{fghi}
TZL COMP3 C3 DT	0.25^{a}	0.25^{a}	0.00^{a}	0.00^{a}	0.13^{i}
ACR O6TZL COMP3 C4 F2	8.50^{a}	4.75^{b}	0.00^{c}	0.00^{c}	3.31^{ghi}
AKPARIKE	33.50^{a}	29.75^{a}	9.50^{c}	20.75^{b}	23.38^{a}
TZL COMP4 C3 F2	18.50^{a}	13.75^{bc}	3.50^{d}	9.25^{c}	11.25^{cde}
TZL COMP4 C3 DT	18.00^{b}	24.75^{a}	9.75^{c}	16.50^{b}	17.25^{b}
BENDE	23.75^{ab}	21.00^{b}	27.00^{ab}	32.25^{a}	26.00^{a}
Aflatoxin Syn3-W	15.00^{a}	15.75^{a}	5.75^{b}	5.72^{b}	10.56^{cde}

SED (1.32) Generation= means followed by the same letter (s) in each row are not significantly different (P≤ 0.05) SED (1.43) Variety = means followed by the same letter(s) in the column are not significantly different (P≤ 0.05)

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Table 4: Mean number of dead adult Sitophilus zeamais in successive generations in different maize varieties of maize.

Variety	F_1	F_2	F_3	F_4	Variety mean
TZLCOMP3C3F2	6.25^{a}	0.50^{b}	2.00^{b}	2.00^{b}	2.69^{bcde}
AflatoxinSynW4	8.50^{a}	2.00^{b}	2.25^{b}	4.75^{ab}	4.38^{abcd}
Obatanpa/TZL COMP4C3	6.00^{a}	1.00^{b}	1.25^{b}	1.00^{b}	2.31^{cde}
Syn/Clfo/Obatanpa TZL COMP3*2	4.75^{a}	1.25^{b}	1.00^{b}	2.25^{b}	2.31^{cde}
Obatanpa/IWDC2 SYN	13.50^{a}	4.00^{b}	3.00^{b}	2.00^{b}	5.63^{abc}
Obatanpa/TZLCOMP3C3	13.00^{a}	2.00^{b}	5.00^{b}	3.00^{b}	5.75^{abc}
Aflatoxin Syn W3	9.75^{a}	1.00^{b}	2.25^{b}	8.00^{a}	5.25^{abc}
TZB-SR	6.00^{a}	8.00^{a}	0.75^{b}	0.25^{b}	3.75^{bcde}
TZL COMP4 C4 F2	20.00^{a}	0.75^{b}	1.50^{b}	1.50^{b}	5.94^{ab}
OGBIA MUNO	1.50^{a}	0.50^{b}	0.50^{b}	0.00^{b}	0.63^{e}
ACR 06 TZL COMP4 C4 F2	6.50^{b}	2.00^{c}	3.50^{bc}	12.50^{a}	6.13^{ab}
TZL COMP3 C3 DT	22.25^{a}	0.00^{b}	0.00^{b}	0.00^{b}	5.56^{abc}
ACR O6TZL COMP3 C4 F2	5.50^{bc}	1.50^{c}	9.50^{b}	14.50^{a}	7.75^{a}
AKPARIKE	3.50^{a}	0.50^{c}	1.25^{b}	0.25^{c}	1.38^{de}
TZL COMP4 C3 F2	3.00^{a}	1.00^{b}	2.25^{a}	0.25^{b}	1.63^{de}
TZL COMP4 C3 DT	2.00^{b}	1.25^{bc}	3.75^{a}	0.50^{c}	1.88^{de}
BENDE	1.25^{a}	1.25^{a}	0.75^{a}	1.00^{a}	1.06^{de}
Aflatoxin Syn3-W	7.25^{a}	2.50^{b}	1.75^{b}	1.25^{b}	3.19^{bcde}

SED (0.76) Generation= means followed by the same letter(s) in each row are not significantly different (P ≤ 0.05)

SED (0.81) Variety = means followed by the same letter(s) in the column are not significantly different (P ≤ 0.05)

Table 5: Mean weight loss of maize grains in successive generations of Sitophilus zeamais

Variety	F_1	F_2	F_3	F_4	Variety total
TZLCOMP3C3F2	0.60^{b}	0.78^{a}	0.18^{b}	0.13^{b}	0.42^{efgh}
AflatoxinSynW4	0.75^{a}	1.03^{a}	0.40^{b}	0.18^{b}	0.59^{cdefg}
Obatanpa/TZL COMP4C3	0.98^{a}	0.95^{a}	0.55^{b}	0.40^{b}	0.72^{bcde}
Syn/Clfo/Obatanpa TZL COMP3*2	1.53^{a}	1.15^{b}	0.53^{c}	0.50^{c}	0.93^{bc}
Obatanpa/IWDC2 SYN	0.65^{a}	0.73^{a}	0.43^{ab}	0.20^{b}	0.50^{defgh}
Obatanpa/TZLCOMP3C3	0.70^{a}	0.63^{a}	0.18^{c}	0.50^{b}	0.50^{defgh}
Aflatoxin Syn W3	0.60^{a}	0.43^{ab}	0.00^{c}	0.25^{b}	0.32^{efgh}
TZB-SR	0.63^{a}	0.20^{b}	0.00^{c}	0.25^{b}	0.27^{fgh}
TZL COMP4 C4 F2	0.10^{ab}	0.25^{a}	0.00^{b}	0.15^{a}	0.13^{gh}
OGBIA MUNO	1.15^{a}	0.55^{bc}	0.93^{ab}	0.15^{c}	0.69^{bcdef}
ACR 06 TZL COMP4 C4 F2	0.63^{a}	0.10^{b}	0.00^{b}	0.18^{ab}	0.23^{fgh}
TZL COMP3 C3 DT	0.50^{a}	0.48^{a}	0.30^{ab}	0.08^{b}	0.34^{efgh}
ACR O6TZL COMP3 C4 F2	0.35^{a}	0.30^{a}	0.00^{b}	0.00^{b}	0.16^{fgh}
AKPARIKE	1.23^{a}	1.78^{a}	1.30^{ab}	1.13^{b}	1.36^{a}
TZL COMP4 C3 F2	1.48^{a}	0.90^{b}	0.63^{bc}	0.40^{c}	0.85^{bcd}
TZL COMP4 C3 DT	1.20^{a}	1.23^{a}	0.98^{a}	0.80^{a}	1.05^{b}
BENDE	1.50^{a}	1.58^{a}	1.15^{a}	1.45^{a}	1.42^{a}
Aflatoxin Syn3-W	1.10^{a}	0.68^{b}	0.13^{c}	0.28^{c}	0.54^{cdefgh}

SED (0.1) Generation= means followed by the same letters in each row are not significantly different ($P \leq 0.05$) SED (0.1) Variety = means followed by the same letters in the column are not significantly different ($P \leq 0.05$)

Temperature and humidity range during the experiment were 25-32^{0}C and 55-85% r.h respectively.

IV. Discussion

Physical characteristics of maize grains as a factor affecting the stability of maize varieties to S. zeamais infestation.

The local cultivars, Bendeand Akparike, recorded the highest numbers of adult S. zeamais progeny, lowest mortality,highest percentages of weight loss and highest oviposition preference. The local cultivar, Bende had the softest kernel and this has been related to susceptibility of maize to maize weevils (Lale and Kartay (2006); Lale and Modu (2003)). However, the cultivar, Akparike had a hard kernel and still sustained high levels of S. zeamais adults. This finding is reported by Adedire et al., 2011, who pointed out that there are factors other than physical ones which may be involved in the resistance of maize cultivars to S. zeamais infestation. Although physical factors have been reported to be more important than chemical factors in conferring resistance on cereal cultivars (Lale and Mustapha, 2000), the presence of secondary compounds such as soluble phenolics and tannins in the cultivar plays some role in imparting resistance (Adedire et al., 2011). This aspect however, was not considered in this study.

The improved varieties', TZL COMP4 C4 F2, TZL COMP3 C3 DT, and TZB-SR were almost immune to S. zeamais infestation, with minimal weight loss and high weevil mortality. Furthermore, the variety TZL COMP3 C3 DT is significantly immune to S. zeamais infestation, there was 100% mortality recorded. This immunity could be as a result oftesta hardness which possibly prevented feeding and oviposition. Other factors include high levels of secondary metabolites as reported by McMullen et al., (2009). The prevailing trend in the study suggests that the local cultivars supported larger populations of S. zeamais.

The general trend from F_1 to F_4 is a decline in number of adult progeny, weight loss and mortality. Progeny emergence over four generations tended to be higher in local varieties and improved varieties with soft kernel. This corresponds with the findings from the study by Siwale et al., (2009); who reported that progeny emergence tended to be higher in susceptible maize cultivars.

In conclusion, varieties TZL COMP4 C4 F2, TZL COMP3 C3 DT, and TZB-SR were the most resistant of the varieties tested, while the local cultivar, Bende and Akparike were the most susceptible to S. zeamais infestation.Therefore maize varieties TZL COMP4 C4 F2, TZL COMP3 C3 DT, and TZB-SR could be cultivated by farmers to reduce S. zeamais damage in storage. This would also serve as a reference for other researchers, a basis for extension services to farmers and possibly a reference for policy making in the agricultural sector. Food security continues to be a matter of serious concern in Nigeria, and the hope is that the findings of this study would aid in the control of maize weevil and ensure lasting and safe storage of maize grains.

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