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Evaluation of the Performance of Different Maize Varieties against *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) Infestation in the Niger Delta Region of Nigeria

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Abstract

The performance of different maize varieties aginst *Sitophilus zeamais* infestation was evaluated in a laboratory. Seventeen maize varieties comprising fourteen hybrids (ACR.97 TZL COMP.1-W, ACR.8328 BNC7, TZL COMP.4C2, OBA SUPER 1 and 2, SINE 9449-SR, IWD SYN C3F2, TZL COMP.1SYN STR-Y, TZSR White and Yellow; 95TZEE-W, MASYN VAR-3 F2, ADV.NCRE-STR and BG 97 TZE COMP.3XL) and three local cultivars (Akparike, Bende and Ogbia muno) were screened to ascertain their level of susceptibility to *S. zeamais* in the study area. Number of adults that emerged from the 17 varieties differed significantly ($P \leq 0.05$) and ranged from 2.00 for the improved variety ADV.NCRE-STR to 62.0 in the local cultivar Bende. Significantly higher weight losses were recorded on local cultivars. Heavier males emerged from the local cultivars Akparike and Bende and lighter ($P \leq 0.05$) weights were recorded on Oba super 1, TZL Comp.4C2, TZSR White, ADV.NCRE-STR and MASYN VAR-3F2. Grain hardness test showed that the hybrid variety MASYN VAR-3F2 (275.12N) was the hardest followed by TZSR-Y (259.42N) and the softest were local varieties Akparike (116.62N) and Bende (91.65N). Seed coat thickness result indicated that the local variety Akparike (0.38mm) had the highest value of seed coat thickness followed by MASYN VAR-3F2 (0.22mm) and the least seed coat thickness was BG 97 TZE COMP.3XL (0.03mm). Results indicated that the local cultivars commonly cultivated in the Niger Delta (Bende, Akparike and Ogbia muno) supported higher *S. zeamais* adult progeny than the improved varieties which had harder seeds and thicker coats. The fact that Akparike which has thick testa was susceptible shows that physical factors alone are not responsible for the observed resistance.

Key Words: *Sitophilus zeamais,* Maize, Variety, Susceptibility and Grain Hardness

1. Introduction

Maize is a major food crop and source of animal feed in Africa, the Americas and Asia as well as a feed for livestock in these regions (Bergvinson, 2000). It is the third most important cereal after wheat and rice globally and the most widely distributed (Purseglove, 1981; Siwale *et al.*, 2009). It is popular for being more resistant to pests and diseases and easier to store and process than traditional food cereals including sorghum and millets in Kenya (Karaya *et al*., 2009).

The major constraint to utilization of maize in the tropics and subtropics is the attack by maize weevil (*Sitophilus zeamais*) (Akob and Ewete, 2007). It is the principal post-harvest pest and infestation commences in the field as soon as maize cobs begin to turn yellow (Haines, 1991). Adult weevils and larvae feed on undamaged grains and frequently cause severe powdering, rendering the product unfit for human consumption (Ofuya *et al.*, 2008). Partially damaged maize grains manifest loss in weight, poor marketability, quality deterioration and low viability (Enobakhare and Law-Ogbomo, 2002). Enobakhare and Law-Ogbomo (2002) and Lale and Kartay (2006) have shown from their studies that some cultivars of maize are relatively resistant to *S. zeamais* attack.

2. Materials and Methods

2.1. Laboratory Screening Of Maize Varieties Against S. zeamais Infestation

A laboratory screening for the most resistant and susceptible maize varieties against *S. zeamais* in the Niger Delta area of Nigeria was carried out under laboratory conditions [temperature (30 ± 2^0C), relative humidity (65±5%)] at the General Laboratory of the Faculty of Agriculture, University of Port Harcourt. Seventeen maize varieties comprising fourteen hybrids [ACR.97 TZL COMP.1-W, ACR.8328 BNC7, TZL COMP.4C2, OBA SUPER 1 and 2; SINE 9449-SR, IWD

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SYN C3F2, TZL COMP.1SYN STR-Y, TZSR White and Yellow; 95TZEE-W, MASYN VAR-3 F2, ADV.NCRE-STR and BG 97 TZE COMP.3XL] and three local cultivars (Akparike, Bende and Ogbia muno) that are normally grown by local farmers in the study area were screened. The fourteen hybrid varieties were obtained from the International Institute of Tropical Agriculture (IITA), Ibadan germplasm, while the three local cultivars were purchased from open markets in Ali-Brada and Mile 3 both in Rivers State, Nigeria. The experimental jars and maize varieties were all sterilized thermally in a hot-air Gallenkamp oven at 60ºC for 2 hours to kill any pest and pathogen that might be present and allowed to acclimatize for 24 hours to laboratory temperature (30ºC) in the laboratory (Atijegbe, 2004; Zakka, 2005). *S. zeamais* culture was raised in the laboratory from infested maize collected in Choba market in Rivers State and reared on a susceptible local maize variety (Coma) in 1-Litre Kilner jars which were left on an open air shelf in the laboratory. To standardize the age of the progeny, the adults were removed after seven days by sieving and the eggs laid were allowed to form the sub-culture. The emerging F_1 were later used for the experiment (Zakka, 2005).

2.2. Sitophilus zeamais Performance On Different Maize Varieties

Six pairs of 2-3 day-old adult *S. zeamais* were introduced into separate jars containing 20g of each maize variety weighed on a sensitive Mettler balance (A & D Electronic balance FX-6000) and left for seven days to oviposit. On the seventh day, the adults were removed by emptying the content of each jar on a piece of white cloth and removing the adults with a soft entomological brush. Subsequently, the content of each jar was carefully returned into the jar and kept in its original position on the shelf and left undisturbed for 37 days to enable the insects to complete their development. The jars were examined daily to observe the emergence of teneral adults so as to determine their daily emergence pattern and developmental rate. Adult count started 15 days after ovipositing females were removed and counted until no teneral adult(s) emerged in each jar for five consecutive days (modified after Throne *et al*., 2002). Each treatment was replicated three times in a completely randomized design (CRD) and kept on open air shelves.

2.3. Sitophilus zeamais Teneral Adult Weight by Sexes

The weight of adult insects by sex was determined by collecting ten males and ten females that emerged from each maize variety by random selection and weighed and the weights recorded. The sexing was done using the snout characteristics such as color and shape, body length and size (Halstead, 1963; Tolpo and Morrison, 1965). The weight of the various maize varieties was taken in batches using an electronic sensitive balance J2003 model and then dried in an oven at 130°C for one hour and cooled for 2 hours before re-weighing. The procedure was repeated until a constant value was obtained. The percent moisture content was calculated as weight of moisture/weight of wet sample x 100 (Obeng-Ofori and Boateng, 2008)

Thus: $Mw = \frac{Wm}{Wo} \times 100\%$

Where Wm=water weight in grain at Mw

Wo= total grain weight at Mw

Since Wo=Wm+Wd

Where: Wd=dry matter weight at Mw moisture content

Therefore $Mw = \frac{Wm}{(Wm + Wd)} \times 100\%$

2.4. Grain Physical Parameters

Seed coat thickness was measured using a Digimatic Vernier Caliper (model Mitutoyo Electronic Digital Caliper Japan) and seed weight loss was determined as described by Lale (2002):

$$\%\text{weight loss} = \frac{[UaN - (U + D)]}{UaN} \times 100$$

Where U= weight of undamaged fraction in a sample

N=total number of grains in a sample

Ua=average weight of one undamaged kernel

D= weight of damaged fraction in a sample

This was confirmed by the modified gravimetric method of Compton *et al*. (1998) by counting damaged grains and weighing of the final samples using the formula

$$\%\text{weight loss} = \frac{Pnd - Pfa}{Pnd}$$

Where Pnd= weight of non-damaged kernels

Pfa= final weight of sample

Grain hardness was determined using CBR Compression machine in the Department of Applied Geology in the Federal University of Technology, Akure, Nigeria. Ten grains were randomly selected from each 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 from the machine by a factor (23.8N/div). Susceptibility index (Dobie, 1974), was determined in order to assess the resistant and susceptible maize varieties.

$$SI = \frac{LogY}{T} \times 100$$

Where SI = susceptibility index

Log Y= log number of F_1 emerged adults

T= mean developmental periods (days)

3. Results

Table 1 shows grain physical properties. Data on seed coat thickness indicated that Akparike, a local cultivar, had the thickest seed coat which was followed by an improved cultivar MASYN VAR-3F2 though it did not differ significantly from most of the other improved varieties. The thinnest seed coat was recorded in BG97 TZE Comp.3XL and local varieties Bende and Ogbia muno. Grain hardness indicated that varieties MASYN VAR-3F2 and TZSR-Y were the hardest though the latter did not differ significantly from TZSR-W and Oba super 2. The four varieties with the softest kernels were ranked in a decreasing order as follows: Ogbia muno > Akparike > ADV.NCRE-STR > Bende.

Table 1. Grain hardness and seed coat thickness as physical parameters.

Maize variety	Grain physical parameter	
	Grain hardness(N)	Seed coat thickness(mm)
ACR 97 TZL Comp. 1-W	227.75^{cd}	0.0750^{c-f}
IWD SYN C3F2	194.65^{ef}	0.0766^{c-f}
OBA SUPER 1	226.10^{cd}	0.0618^{d-f}
ACR.8328 BNC7	216.82^{c-e}	0.1580^{b-e}
TZL Comp.4C2	171.36^{f}	0.1982^{bc}
SINE 9449-SR	211.8^{de}	0.1776^{b-d}
ADV.NCRE-STR	106.13^{gh}	0.1120^{b-f}
BG 97 TZEComp.3XL	134.46^{g}	0.0253^{f}
AKPARIKE	116.62^{gh}	0.3820^{a}
TZL Comp. 1SYN STR-Y	206.09^{de}	0.1872^{b-d}
BENDE	91.65^{h}	0.0448^{ef}
95 TZEE-W	203.25^{de}	0.1710^{b-d}
MASYN VAR-3 F2	275.12^{a}	0.2240^{b}
OBA SUPER 2	242.66^{bc}	0.1790^{b-d}
TZSR White	240.37^{bc}	0.0988^{b-f}
TZSR Yellow	259.42^{ab}	0.0960^{c-f}
OGBIA MUNO	131.65^{g}	0.0643^{d-f}

Means with the same letters in the same column are not significantly ($P \leq 0.05$) different by Student-Newman-Keuls test

Table 2 shows that the mean number of adults that emerged from the 17 varieties were significantly different ($P \geq 0.05$) and ranged from 2.00 for the improved variety ADV.NCRE-STR to 62.0 for the local variety Bende. The number of adults that emerged on the improved varieties ranged in the increasing order: ADV.NCRE-STR < TZL Comp.4C2 < IWD SYN C3F2 < TZSR White < BG 97 TZE Comp.3XL < SINE9449-SR < OBA SUPER 1. The effect of pest activities on weight losses is also shown in Table 2.

Table 2. Mean number of adult progeny and grain weight (g) loss on 17 different maize varieties.

Maize variety	Number of emerged adults	Grain weight loss (g)
ACR 97 TZL Comp. 1-W	23.00^{cd}	2.20^{b-d}
IWD SYN C3F2	04.33^{f}	0.40^{de}
OBA SUPER 1	16.00^{de}	1.56^{b-e}
ACR.8328 BNC7	17.00^{de}	1.76^{b-e}
TZL Comp.4C2	02.67^{f}	0.27^{e}
SINE 9449-SR	10.67^{ef}	1.00^{c-e}
ADV.NCRE-STR	02.00^{f}	0.20^{e}
BG 97 TZE Comp.3XL	05.00^{f}	0.56^{c-e}
AKPARIKE	46.00^{b}	5.33^{a}
TZL Comp. 1SYN STR-Y	19.67^{c-e}	1.90^{b-d}
BENDE	62.00^{a}	7.67^{a}
95 TZEE-W	19.67^{c-e}	1.96^{b-d}
MASYN VAR-3 F2	19.67^{c-e}	1.96^{b-d}
OBA SUPER 2	24.00^{cd}	2.46^{bc}
TZSR White	04.67^{f}	0.53^{c-e}
TZSR Yellow	17.00^{de}	1.73^{b-e}
OGBIA MUNO	27.67^{c}	3.26^{b}

Means with the same letters in the same column are not significantly ($P \leq 0.05$) different by Student-Newman-Keuls test

A significantly higher weight loss was recorded in the local varieties Bende and Akparike and closely followed by Ogbia muno and in the improved varieties Oba super 2 and ACR97 TZL Comp.1-W, although they did not differ significantly from those of BG97 TZE Comp.3XL, TZSR White and TZSR Yellow. The least weight losses were recorded on the improved varieties ADV.NCRE-STR, TZL Comp.4C2 and IWD SYN C3F2.

Table 3 shows the mean weights of male and female adults that emerged from each variety , and it indicates that heavier males emerged from the local cultivars Akparike and Bende than those that emerged from the improved varieties 95TZEE-W, SINE 9449-SR, TZL Comp.1SYN STR-Y, IWD SYN C3F2. However, lighter ($P < 0.005$) weights were recorded on Oba super 1, TZL Comp.4C2, TZSR White, ADV.NCRE-STR and MASYN VAR-3F2, Oba super 2, TZSR Yellow, BG97TZE Comp.3XL, ACR.8328BNC7 and ACR97TZL Comp.1-W varieties. Heavier females were recorded in the local cultivar Akparike which was closely followed by those from ACR97TZL Comp.1-W, TZL Comp. 1SYN STR-Y, 95TZEE-W, TZSR Yellow, SINE 9449-SR, ACR.8328 BNC7, Bende and Obgia muno. Lighter adult females emerged from IWD SYN C3F2, TZSR White and ADV.NCRE-STR, BG97 TZE Comp.3XL, MASYN VAR-3F2, Oba Super 2 and Oba Super 1.

Peak of emergence was recorded within the first 7 days on all the varieties (Figures 1a, 1b, 1c and 1d) and two peaks were recorded on Akparike and Ogbia muno varieties (Figures1a and 1c); however, highest peaks were recorded on the local cultivars (Figures 1a, 1b and 1c) with Bende (Figure 1b) recording the highest peak and an improved variety ACR.8328BNC7 had irregular peaks (Figure 1d).

Table 3. Mean weight (g) of males and females of *S. zeamais* that emerged from 17 different maize varieties.

Maize variety	Weight (mg)	
	Male	Female
ACR 97 TZL Comp. 1-W	2.9^{b-e}	5.7^{b}
IWD SYN C3F2	3.3^{a-d}	2.7^{e}
OBA SUPER 1	2.4^{e}	3.9^{c-e}
ACR.8328 BNC7	2.8^{c-e}	5.2^{bc}
TZL Comp.4C2	2.4^{e}	3.0^{e}
SINE 9449-SR	3.4^{a-c}	4.6^{b-d}
ADV.NCRE-STR	2.5^{e}	3.0^{e}
BG 97 TZE Comp.3XL	2.8^{b-e}	3.1^{de}
AKPARIKE	3.9^{a}	7.5^{a}
TZL Comp. 1SYN STR-Y	3.3^{a-d}	5.9^{b}
BENDE	3.6^{a}	5.2^{bc}
95 TZEE-W	3.4^{ab}	5.9^{b}
MASYN VAR-3 F2	2.7^{e}	3.8^{c-e}
OBA SUPER 2	2.8^{de}	3.9^{c-e}
TZSR White	2.6^{e}	2.7^{e}
TZSR Yellow	2.8^{de}	6.1^{b}
OGBIA MUNO	2.9^{b-e}	5.4^{bc}

Means with the same letters in the same column are not significantly ($P \leq 0.05$) different by Student-Newman-Keuls test

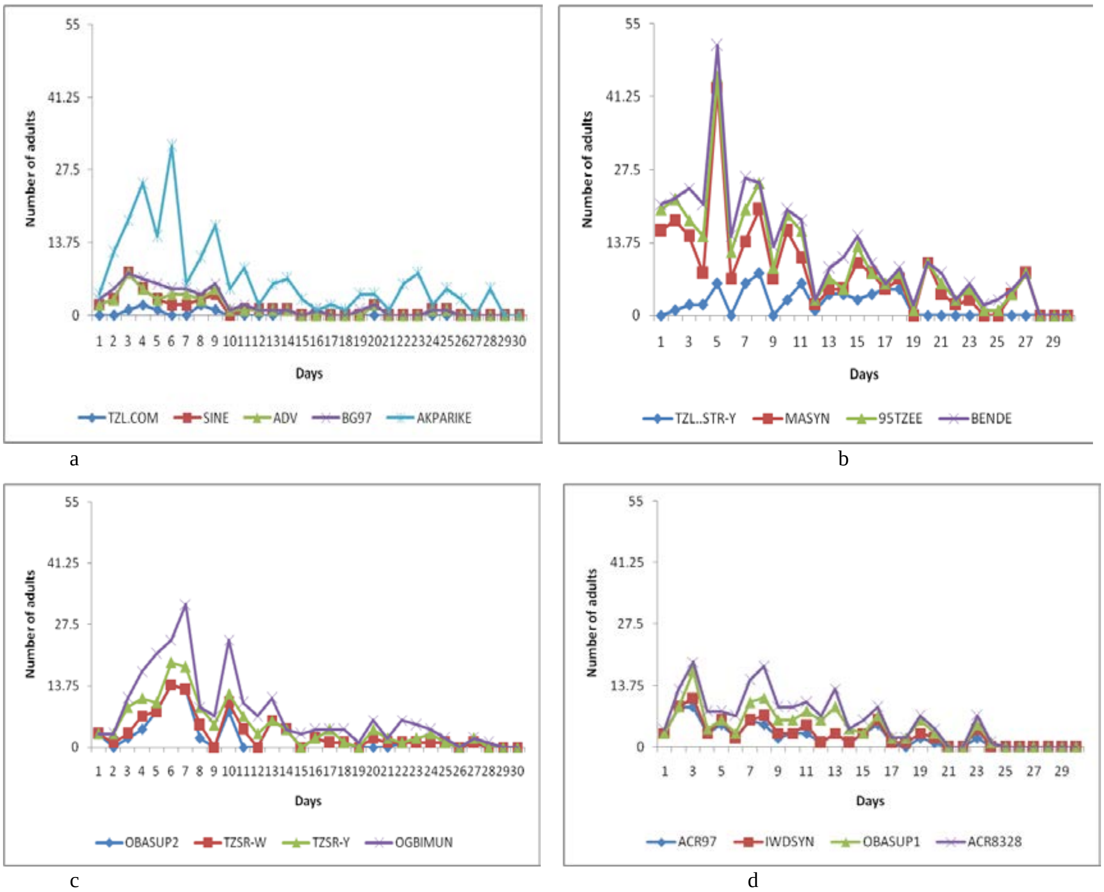

Figure 1 a-d. Emergence pattern of *S. zeamais* on different maize cultivars

4. Discussion

The result of this study indicates that the grains of the local varieties had thinner seed coats and softer kernel compared with the improved varieties which had thicker seed coats and harder kernels. These local varieties supported higher *S. zeamais* adult progeny than the improved varieties. The physical characteristics of the seed coat affect oviposition and/or egg-hatch in beetles (Lale and Makoshi, 2000; Lale and Kartay, 2006). These physical factors, among others, are most likely to be the contributory factors that affected the differences in the development of the adult *S. zeamais* that eventually emerged from the different varieties. The resistance exhibited by the improved varieties has been attributed to mechanical barriers provided by thick testae and hard grains (Lale and Yusuf, 2001; Ashamo, 2001; Lale and Kartay, 2006). The fact that Akparike which has a thick testa was susceptible shows that physical factors alone are not responsible for the observed resistance. In earlier studies hydroxycinnamic acids (phenolics), E-ferulic acid and protein content and other chemical factors have been implicated (Dobie, 1977; Serratos *et al*., 1987; Arnason *et al*., 1992).

Although the precise mechanism by which the factors impede *S. zeamais* development is yet to be well understood, the result from this work suggests that the soft texture of the local varieties may have contributed at least in part to their susceptibility. The seed coat thickness and grain hardness served as a barrier to the penetration of the endosperm by *S. zeamais* amongst the improved varieties which proved to be less susceptible to infestation. It is therefore, possible that the harder endosperm of the improved maize varieties poses some degree of difficulties for the development of the beetles thereby interfering with their ability to obtain the desired nutrient for oviposition and growth thus resulting in poor development (Lale and Yusuf, 2001). The higher weight losses observed in the local cultivars after a period of 35 days of the experiment can be attributed to the higher numbers of adult progeny that developed in these cultivars thus indicating a greater preference of such cultivars by *S. zeamais* as suitable substrates for development. The implication of this is that if theses maize varieties are left unprotected it could lead to economic weight losses in those maize cultivars as compared to the improved varieties.

Differences in weights of male and female beetles that developed in different substrates were observed in earlier studies (Danho *et al.*, 2002; Zakka, 2005). The improved variety ADV NCRE-STR that proved relatively resistant to the pest had heavier adults emerging from it; this could be due to its ability to supply nutrients that can encourage robust physical development of the pest but possibly possesses an inhibitory factor that perhaps affects oviposition, larval or pupal development. In contrast, those improved varieties that did not support much development had equally lighter adults emerging from them, and this might be attributed to lack of required nutrients for optimal development.

Adedire (2001) gave the life cycle of *S. zeamais* to be about 35 days. Adult emergence from ACR97TZL Comp1-W, ACR.8328 BNC7, SINE 9449-STR, BG97TZE Comp.3XL, Akparike, Bende, MASYN VAR-3F2, 95TZEE-W and Oba Super 2 commenced on the 37th day of introduction and late emergence on improved varieties IWD SYNC3F2 and ADV NCRE-STR commenced on the 39th and 42nd day, respectively. This delayed development was reported by Lale and Maina (2002) on groundnut cultivars 'Jato', 'Yar Damboa' and 'Kampala' which restricted development by prolongation of the bruchid's life cycle. Adult emergence stopped early (10 days after commencement) on varieties ADV NCRE-STR and TZL Comp.4C2 while it lasted for up to 30 days on the susceptible local cultivars Ogbia muno and Akparike. The relative resistance shown by the improved varieties especially variety ADV NCRE-STR to *S. zeamais* infestation through prolongation of development and reduction of adult progeny may be attributed principally to antibiotic factors in the endosperm and difficulty in obtaining optimum quantity of nutrients needed for growth from the harder endosperm (Jansen and Nylin, 1997; Barros and Zucoloto, 1999). Other known factors that determine suitability as a breeding medium are morphology, environmental conditions, age and size of individuals (Stejskal and Kucerova, 1996; Johnson and Kistler, 1987) and competition (Siemens *et al*., 1991).

The highest number (37/day) of adult progeny recorded on Bende gives a clear indication of the pest load it can accommodate thus making it highly susceptible to infestation. If such an emergence level is continued over the emergence period of 30 days recorded, then within a short time the whole crop stands the risk of having 100% devaluation thereby leading to high grain loss. From the rate of emergence of the adult progeny on the local cultivars (Figs 1a, 1b and 1c), it means that if they are left unprotected, infestation could build up to an economic damaging level within the first few days of storage, thereby making the farmer to incur high quantitative and qualitative losses. The discovery of ADV NCRE-STR, TZL Comp.4C2, IWD SYN C3F2 and other improved varieties which are resistant to *S. zeamais* infestation in comparison with the local cultivars grown in the Niger Delta underlines the need for a change from the cultivation of the local cultivars in preference for the improved varieties for maize. It may also lead to the extension of the shelf life of maize in store, though it will require extensive extension work to sell the idea to the local farmers. It is also important to note that as Cavanaugh *et al*. (1995) reported, increased hardness of endosperm of grains in maize is desirable for dry milling, storage and export purposes; breeding intentionally for grain hardness would be an effective strategy for reducing the menace of *S. zeamais* on maize grains in storage.

5. Conclusion

The results of the study suggest that in order to improve maize storage, farmers need to adopt the cultivation of the improved cultivars. They also give indication of the need for breeders to develop cultivars with thick testae and hard endosperm (Cavanaugh *et al*., 1995; Lale and Yusuf, 2001; Lale and Modu, 2003; Lale and Kartay, 2006).

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