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The Response of Different Maize Varieties to Three Generations of *Sitophilus zeamais* (Motsch.) Infestation

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Abstract The stability of resistance of fifteen maize varieties to infestation by three generations of *Sitophilus zeamais*, was investigated in the laboratory of Faculty of Agriculture, University of Port Harcourt, Nigeria. The experiment was laid out in a completely randomized design (CRD) and each treatment was replicated three times. Developmental period, number of adult progenies, and weight loss were variables used to differentiate the performance of the three generations on maize varieties. Grain hardness, weight, length, width and moisture content of the maize seeds were also determined for the various varieties .The result shows that adult progeny development decreased progressively with increasing generation in all the varieties and that influence of grain hardness on the resistance of maize varieties to infestation by *S. zeamais* was not consistent.

Keywords Stability, *Sitophilus zeamais*, Generation, Maize, Resistance

1. Introduction

Maize (*Zea mays* L.) is the most widely distributed and the third most important cereal after wheat and rice . It is also the third most important cereal in Nigeria after sorghum and millet[1,2]. Maize is principally used for human consumption and livestock feed[3]. It can be processed for oil, starch, alcohol and adhesives, explosives, paints, ceramics, shoe polish, dyes, rubber substitutes and many more[4]. World leading producer of maize is USA, which produces about 40% of the world's total production[4]. In Ethiopia, maize ranks first[5]. Increasing and improving maize production and utilization have been suggested as one major strategy for alleviating the specter of hunger and malnutrition that appears to be perpetually hanging over many African countries[6].

A major biotic constraint to utilization of maize in the tropics and subtropics is the attack by insect pests especially the maize weevil, *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae)[7] which is a cosmopolitan pest of sound and wholesome grains in the tropics and temperate regions of the world[8]. It is a primary pest that attacks other crops such as rice, guinea corn (sorghum) dry yam products, groundnut, cowpea, millet, dry cassava, cocoyam and beniseed (sesame) in Nigeria[9,10]. The basic life cycle of *S. zeamais* is well known. The adult female beetle bores a hole in the grain and deposits a single egg and upon eclosion, the larva feeds exclusively within the grain and sooner or later pupates.

The adult emerges outwards the grain through a circular characteristic hole[2].

Damaged maize grains have reduced weight, poor marketability and low viability[11]. Weight losses of 30-80% in storage due to maize by *S. zeamais* infestation have been reported for many areas[12].

Varietal differences in the susceptibility of maize to infestation and damage by *S. zeamais* have been observed[13, 14, 15, 11, 16]. However, even the most promising amongst traditional as well as newly developed crop varieties succumb to the storage pest after a period of time[17]. Nevertheless, the use of less susceptible maize varieties in conjunction with other control methods to be part of an integrated pest management program, would provide a long lasting system to maintain insect populations in stored maize in the tropics at an acceptably low level[15]. However, there is the need to routinely screen new crop varieties for resistance to stored product insect pests, because the introduction of improved varieties has sometimes been accompanied by an increase in susceptibility to stored product insects[18, 14]. Despite the importance of *S. zeamais,* data on stability of the resistance of maize varieties against its infestation is lacking in the literature. An understanding of the ability of advancing generation of maize weevil to infest resistant maize varieties will assist in the development of improved management practices for the control of this pest. In this study, 15 improved maize varieties were screened for relative susceptibility to attack by 3 generations of *S.*

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zeamais in order to assess the stability maize weevil infestation and to determine the damage done by different generations of *S. zeamais* on the different maize cultivars.

2. Materials and Methods

The study was carried out in the Faculty of Agriculture General Laboratory at the University of Port Harcourt, Nigeria. For this experiment, 15 varieties of maize were collected from the International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria, and used to evaluate their performance against infestation by *S. zeamais*. The varieties comprised PVA SYN 13, PVA SYN 16, DTSTN 1OW, WDT SYN IWD C3 SYN F2, OBATANPA/TZL COMP.3 C3 F2, POP 66-SR/DMR-LSRY/DMR LSRYF2 and TZL COMP.3 C4. Others are TZL COMP. /SYN STR-F1, TZL COMP.3 C3 and TZL COMP./STR SYN-W1, STR SYN W/F2, IWD SYN C3F2, OBA SUPER 1, OBA SUPER 2, and Z DIPLO BC4C3YF2. The grains were sterilized in a hot air oven at 50°C for 24 hours to kill any mites and insect pests that might be present.

2.1. Insect Culture

Maize infested with *S. zeamais* was obtained from Choba Market in Rivers State, Nigeria. *S. zeamais* adults were sieved out using a plastic sieve and the culture was established on a known weevil susceptible local maize variety (Bende) and kept in 1-L Kilner jars to raise a sub culture of known age which was used for the experiment.

2.2. Determination of Physical Parameters of the Seed

Length and Width: 100 randomly selected grains from each maize variety were individually weighed on a sensitive Mettler balance sensitive to 0.001g Model JS 2003. The length and width of 10 randomly selected maize grains from each variety were individually measured using an electronic Vernier caliper.

Moisture content: moisture content of each maize variety was determined by weighing 10g from each variety and drying in an oven at 120°C for 2 hours, after which they were removed and re-weighed this continued until a constant value was obtained and expressed mathematically as:

$$MC = \frac{Y - Z}{Y} x100$$

Where:

Y = initial weight

Z = Final weight

Mc = % moisture content on wet basis

Grain hardness: 10 grains were randomly selected from each cultivar and tested for grain hardness using a California Bearing Ratio (CBR) machine. Each grain was carefully placed in a vertical position on the stage meter and crushed; the hardness of the grain was calculated by multiplying the value that was obtained from the machine by a factor (23.8 N/div).

Bioassays: three replicates of 10g of grains of each maize variety were placed in separate 50 ml transparent plastic containers covered with lids. Four pairs of newly emerged *S. zeamais* were introduced on each 10g lot of maize variety and were allowed to oviposit for seven days after which they were removed. The experimental containers were left undisturbed in the laboratory until the emergence of the F_1 generation. The F_1 adult weevils were counted over a period of 14 days. In the second set of the experiment, four pairs of *S. zeamais* that emerged in the F_1 from each variety were introduced to start up the F_2 generation from which their adult progeny were also used to infest the maize grains in the F_3 generation.

The experiment was carried out in a completely randomized design (CRD) and each treatment was replicated three times. Data were collected on developmental period, number of adult progeny in each generation, grain weight loss, grain moisture content before and after the experiment and grain length and width.

The level of damage caused in each of the 3 generations of *S. zeamais* on the 15 maize cultivars was analyzed; developmental period, total numbers of adult progeny and grain physical parameters were other parameters analyzed. Data collected were subjected to analysis of variance, and means were separated using the Student-Newman-Keuls test (SNK) at 5% level of probability. For the generational study the data were subjected to two factor ANOVA with maize variety and generation of adult weevil progeny as factors and differences between means were handled in a similar manner.

3. Result

Table 1 shows the mean values for physical parameters of maize varieties screened against *S. zeamais.* Data on the grain hardness indicated that maize cultivar Z DIPLO BC4 was significantly harder ($P \leq 0.05$) although it did not differ statistically ($P > 0.05$) from other varieties like PVA SYN 13, OBATANPA/TZL COMP. 3 C4 F2, IWD SYN C3F2 and OBA SUPER 1; the softest kernel was recorded in TZL COMP.3 C4. Maize variety WDT SYN IWD C3 SYN F2 contained the heaviest grains and POP 66-SR/DMR-LSRY/ DMR LSRYF2 and TZL COMP./STR SYN-W1 contained the lightest grains.

The table also shows that the highest weight loss was recorded in OBA SUPER 1(9.556g) which was followed by TZL COMP./STR SYN-W1 and the least weight loss was recorded in varieties TZL COMP. 3 C4. Other grain parameters analyzed were grain length and width and the result shows that variety DT SYN 10W had the highest grain width and the least grain width was recorded in OBA SUPER 2, while grain length was significantly higher in WDT SYN IWD C3 SYN F2 with varieties OBA SUPER 2 and IWD SYN C3 F2 having the least measurement of length. At the end of the experiment percentage grain moisture content ranged from 9.4 in STR SYN W/F2 to 9.0 in OBA SUPER 1.

Table 2 shows the mean number of *S. zeamais* adults that developed in different varieties of maize in the three generations. Development of adult weevil progeny decreased progressively with increasing generation in all the varieties. OBA SUPER 1 had the highest total number of adult progeny, although it did not differ significantly (p> 0.05) from TZL COMP./STR SYN-WI and STR SYN W/F2 and the least number of adult progeny was recorded on TZL COMP. 3 C4.

Result of mean developmental period of *S. zeamais* shows that development was significantly longer in PVA SYN 16, although it did not differ significantly (P>0.05) from a similar variety PVA SYN13. TZL COMP.3 C4 recorded the shortest developmental period.

4. Discussion

The study has clearly shown that adult weevil progeny development decreased progressively in all the varieties with increasing generation. In a similar study involving resistant varieties of bambara groundnuts (*Vigna subterranea*) and *Callosobruchus maculatus,* Ajayi and Lale[19] observed that development time increased significantly and that both susceptibility and bruchid development decreased significantly in F4, F5 or F6 generation relative to the levels of the same parameters in F1 or F2 generation. These authors opined that it is possible that the higher levels of trypsin inhibitor activity in raw bambara groundnut progressively incapacitates *C. maculatus* physiologically and this perhaps leads to reduced survival and reduced fecundity of the beetles. The findings of the present study corroborate the observations of these authors as adult weevil development declined progressively as the generation of *S. zeamais* increased. MacMullen *et al*[20] reported that the secondary metabolites contained in improved maize varieties appear to have a chronic effect on the weevil's reproductive physiology. Maize cultivars are known to have various secondary compounds, especially tannins and soluble phenolics which confer on them varying degrees of protection against herbivory[20, 21].

Table 1. Mean values of physical parameters of maize varieties screened against *Sitophilus zeamais*

Maize variety	Grain hardness (Newton)	Grain weight (g)	Grain weight loss (g)	Grain width (mm)	Grain length (mm)	% Grain moisture content
Oba super 1	320.82^{a-c}	0.2424^{e-g}	9.556^{a}	7.977^{cd}	8.077^{e}	9.0
Oba super 2	190.40^{d-e}	0.2251^{fg}	0.444^{e}	7.257^{de}	7.530^{e}	9.2
PVA SYN 16	228.48^{c-e}	0.2618^{c-g}	3.000^{c-e}	8.686^{ab}	9.993^{bc}	9.1
DT STN 1OW	242.76^{c-e}	0.3072^{a-c}	3.111^{c-e}	9.056^{a}	9.943^{ab}	9.2
IWD SYN C3F2	321.30^{a-c}	0.2790^{b-e}	2.111^{de}	7.821^{de}	8.421^{de}	9.1
OBATANPA/TZL COMP.3 C3 F2	354.58^{ab}	0.3072^{a-c}	5.222^{b-d}	8.130^{b-d}	10.260^{bc}	9.2
POP 66-SR/DMR-LSRY/DMR LSRYF2	309.40^{a-c}	0.2174^{g}	2.556^{de}	8.401^{a-d}	9.891^{bc}	9.2
PVA SYN 13	385.56^{a}	0.2618^{c-g}	2.889^{c-e}	7.981^{cd}	10.418^{bc}	9.1
STR SYN W/F2	221.34^{c-e}	0.2680^{c-f}	6.556^{a-c}	7.832^{c-e}	9.895^{bc}	9.4
TZL COMP. ISYN STR-F1	287.98^{a-d}	0.2763^{b-e}	3.111^{c-e}	8.153^{b-d}	10.819^{ab}	9.2
TZL COMP./STR SYN-W1	254.66^{b-d}	0.2510^{g}	7.889^{ab}	7.731^{b-d}	9.254^{cd}	9.1
TZL COMP.3 C3	233.24^{c-e}	0.2562^{d-g}	5.111^{b-d}	8.502^{a-c}	9.929^{bc}	9.2
TZL COMP.3 C4	138.04^{e}	0.3219^{a-d}	0.222^{e}	8.737^{ab}	10.586^{ab}	9.2
WDT SYN IWD C3 SYN F2	290.36^{a-d}	0.339^{a}	3.778^{c-e}	8.174^{b-d}	11.410^{a}	9.1
Z DIPLO BC4C3YF2.)	397.47^{a}	0.2937^{a-d}	1.000^{e}	8.737^{ab}	10.635^{ab}	9.2

Table 2. Mean number of *Sitophilus zeamais* adults that developed in different varieties of maize in three generations

Maize Variety	Generation of *S. zeamais*			Adults & their Developmental period	
	F_1	F_2	F_3	Adults progeny	Period (days)
Oba super 1	43.00±3.21	20.66±1.45	13.66±5.81	25.777^{a}	29.444^{ab}
Oba super 2	5.00±2.51	3.00±0.57	1.66±0.33	3.222^{d}	21.444^{de}
PVA SYN 16	14.67±2.33	11.00±2.30	5.33±1.33	10.333^{b-d}	35.667^{a}
DT STN 1OW	25.33±8.74	11.66±8.74	3.66±2.66	13.555^{a-d}	34.333^{ab}
IWD SYN C3F2	21.66±5.20	7.66±2.90	3.33±1.85	10.887^{b-d}	31.333^{ab}
OBAT ANPA/TZL COMP.3 C3 F2	27.33±3.66	17.00±2.64	6.00±1.52	16.777^{a-d}	33.556^{ab}
POP 66-SR/DMR-LSRY/DMR LSRYF2	35.00±3.51	11.00±2.08	4.00±2.30	16.666^{a-d}	25.556^{bc}
PVA SYN 13	9.33±0.88	6.33±1.76	5.00±0.58	6.888^{b-d}	33.556^{ab}
STR SYN W/F2	29.66±5.23	18.66±1.20	11.66±0.66	20.000^{a-c}	33.444^{ab}
TZL COMP. ISYN STR-F1	23.06±10.71	8.33±2.33	5.66±2.18	12.555^{a-d}	28.111^{a-c}
TZL COMP./STR SYN-WY	37.33±7.17	23.00±9.29	13.33±5.54	24.554^{ab}	28.889^{a-c}
TZL COMP.3 C3	23.66±3.52	15.33±2.18	12.00±1.52	17.000^{a-d}	33.000^{ab}
TZL COMP.3 C4	11.33±6.88	4.00±0.57	3.00±1.00	6.111^{dc}	18.778^{e}
WDT SYN IWD C3 SYN F2	23.66±4.97	13.66±1.76	4.33±1.76	13.888^{a-d}	29.778^{ab}
Z DIPLO BC4C3YF2.)	6.33±0.88	2.33±0.33	1.33±0.66	3.333^{d}	23.556^{cd}

The study has shown that there is no clear effect of physical characteristics (grain hardness, weight, length and width) of maize as an index of determining susceptibility or resistance to *S. zeamais* activity. For instance OBA SUPER 1 that had harder seed supported more adult *S. zeamais* progeny. On the contrary, Z DIPLO B C4 C3 YF2 also had harder seed but recorded less adult *S. zeamais* progeny. This confirms the findings of[15] who did not observe a clear influence of kernel hardness on the susceptibilities of the 31 varieties screened for resistance to infestation by *S. zeamais*. The correlation between kernel quality traits and kernel texture with percentage weight loss due to *S. zeamais* infestation and multiplication in many maize genotypes were similarly found by[16] to be non-significant, although some other workers have found a relationship between susceptibility and hardness. For instance,[22] found a positive correlation between the softness of maize varieties and their susceptibility to the maize weevil. Vowotor *et al*[23] found that in general, larvae developed significantly more slowly on varieties with large, hard kernels, than in small–seeded soft ones.

The higher weight losses observed in Oba Super 1, TZL COMP./ STR SYN W 1 and STR SYN W/F2 after a period of 14 days of experiment can be attributed to higher numbers of adult progeny that developed in these varieties thus indicating a greater preference of such varieties by *S. zeamais* as suitable substrates for development. The implication is that if these maize varieties are left unprotected it could lead to economic weight losses in these varieties as compared to the other varieties and the highest number of adult progeny recorded on OBA SUPER 1 gives a clear indication of its being highly susceptible to infestation. If such an emergence level is continued over the period of 14 days recorded, then within a short time the whole crop stands the risk of having 100% devaluation thereby leading to high grain loss[24].

The highest percentage moisture content was recorded on Oba super 1 which supported significantly more adult *S. zeamais* progeny and highest weight loss. This finding concurs with that of[25] who recorded that high moisture content increases activities of biotic agents, thus increasing loss in storage. It has been observed in this study that significantly fewer adults developed with increasing generation suggesting the ability of resistant maize varieties to maintain this trait over a reasonably long time and thus provide sustained protection against *S. zeamais* infestation. The study has also shown that grain hardness does not consistently confer resistance to *S. zeamais* infestation on resistant maize varieties[26], instead it has shown that chemical factors also play a significantly role in conferring resistance.

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