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Influence of Morphological and Morphometric Characteristics of some Maize Varieties against *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) Infestation in Northeastern Nigeria

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Abstract
Background: *The study was carried out to determine the morphometric characteristics of twenty improved and five local maize genotypes against Sitophilus zeamais Motschulsky (Coleoptera: Curculionidae) infestation in Northeastern Nigeria. The study was conducted in the Laboratory in a Completely Randomized Design (CRD) replicated three times. The morphological and morphometric characteristics of these maize genotypes as well as the susceptibility index (SI) were determined. Data collected were analyzed using ANOVA and means separated using Tukey Kramer HSD test at P>0.05. Result of the morphological characteristics of the maize grains show that two color types: white and yellow were differentiated, while shapes were hexagonal, oval and rectangular. In respect to face-type, the varieties were dent, semi dent, flint or dent-flint and all the varieties were smooth in texture. However, all these characteristics did not confer resistance among the maize varieties. The morphometric characteristics, such as grain length, width, thickness, 100 grains weight and hardness, only grain hardness confers resistance to insect attack which ranged from 121.40 to 382.20 Newton in SAMMAZ 34 and SAMMAZ 16, respectively. The susceptibility index (SI) ranged from 3.4 to 6.5. Based on Dobie rating, SAMMAZ 17, SAMMAZ 21 and SAMMAZ 34 were moderately susceptible with higher* F_1 *progeny production of 53.3 to 56.0 and lower median developmental time of 26.7 to 28.3. So also, SAMMAZ 16, SAMMAZ 20, SAMMAZ 25 and SAMMAZ 29 were resistant with lower* F_1 *progeny production of 26.0 to 35.0 and higher median developmental time of 38.0 to 42.0, while the rest were moderately resistant. This research work has provided reliable information on the characteristics that confer relative resistance of the tested maize that can serve as selection guide to avoid economic damage by S. zeamais.*

Keywords: *Sitophilus zeamais, Varieties, Susceptible, Resistant, Morphometric*

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I. Introduction

Maize *Zea mays* (L.) is an important food, cash and industrial crop (FAO, 2003; Jones *et al*., 2011) and one of the staple foods in the southern, northern and middle zones of Nigeria and the most widely cultivated cereal crop in the country after guinea corn and millet. Maize provides families with much needed nutrients such as carbohydrates, proteins, fats, vitamin B and minerals (Tongjura *et al*., 2010) and a primary source of energy in developing countries where it contributes up to 60% and 30% of the diet's energy and protein, respectively (Mlynekov *et al*., 2013). The whole grain, freshly green or dried, may be used or may be processed by wet or dry milling methods to give a variety of food products like; Ogi (in hot and cold forms), tuwo, donkunnu, maasa, couscous, akple, gwate, nakia, egbo, abari, donkwa, ajepasi, aadun, kokoro, elekute etc. (Abdulrahaman and Kolawale, 2006).

Both in the field and storage, insects are the principal cause of maize grain losses (Kabir *et al*., 2009; Dubale *et al*., 2012; Simbarashe *et al*., 2013). Although, many types of insects occur, but it has been reported that the maize weevil, *Sitophilus zeamais* Motschulsky is a very serious primary pest of stored maize grains which cause severe losses in stored maize grain in Africa (Ofuya and Lale 2001; 2005; Mebarkia *et al*., 2009; Tongjura *et al*., 2010). In Nigeria, it was revealed that this weevil causes weight losses of maize stored for 3 to 6 months to about 10-30%. Under severe infestations, this maize weevil can cause up to 90% loss of stored grain (Giga *et al*., 1991; Tadele *et al*., 2011).

The economic importance and wide distribution of *Sitophilus* species have prompted many researchers to go into studies on various aspects of the weevils, especially *S. zeamais* (Danjuma *et al*., 2009; Owolabi *et al*., 2009; Makate, 2010) with the aim of developing of an affordable alternatives which offer same control levels of weevils as synthetic insecticides (Parwada *et al.*, 2012). The current trend in stored-product pest control is to use reduced-risk or low-toxicity insecticides as a replacement for conventional grain protectants, chiefly organophosphates. This led to the use of resistant maize varieties (Temesgen and Waktole, 2013). The use of resistant varieties is effective, technically easy, environmentally benign, economically feasible and acceptable by the society. Some workers have already documented that resistance in stored maize to insect attack is related to some physical, chemical and biochemical characteristics of a maize variety (Adedire *et al.*, 2011). Thus, it is deemed possible to use varietal resistance as an integrated management option of *S. zeamais*. Therefore, this research is aimed at determining the morphological and morphometric characteristics of different maize varieties and to also screen these maize varieties for their resistance to the maize weevil *S. zeamais.*

II. Materials And Methods

Study Site

The experiment was conducted in the Laboratory of the Department of Crop Protection, Modibbo Adama University of Technology, Yola. Yola is located in the Northern Guinea Savannah Agro-Ecological Zone of Nigeria at latitude 90^{o} 14`N, longitude 12$^{o}$ 28`E and altitude 190.5m and has the minimum and maximum rainfall, temperatures and relative humidity of 0.80 and 4.92ml; 27^{o}C and 42^{o}C and 35% and 75%, respectively (DMSY, 2017).

Sources of Experimental Materials

Sources of maize genotypes

A total of twenty five (25) maize genotypes, comprising twenty (20) improved ones acquired from the Institute for Agricultural Research (IAR) Samaru, Zaria, Kaduna State, viz; SAMMAZ 11, SAMMAZ 13, SAMMAZ 14, SAMMAZ 15, SAMMAZ 16, SAMMAZ 17, SAMMAZ 18, SAMMAZ 19, SAMMAZ 20, SAMMAZ 21, SAMMAZ 22, SAMMAZ 25, SAMMAZ 26, SAMMAZ 27, SAMMAZ 29, SAMMAZ 30, SAMMAZ 33, SAMMAZ 34, SAMMAZ 37 and SAMMAZ 38. Five (5) local cultivars sourced from Adamawa State Agricultural Development Programme (ADP), Adamawa State, Nigeria viz; Baleji, Bataji, Bodeji, Daneji, and Saksi.

Insect Culture

Sitophilus zeamais population was obtained from naturally infested maize grains obtained from a local grain merchant in Yola, Adamawa state, Nigeria. The insects were reared on a susceptible local maize variety "Saksi" (Agesa *et al.,* 2017) in two 1-litre transparent plastic bucket and routinely maintained to provide weevils of similar age for the study. Each bucket contained 100 adults of *S. zeamais* per 500 g grains. The buckets were then covered with muslin cloth to allow aeration and to prevent escape of the weevils. All parents *S. zeamais* in each bucket was removed after seven days by sieving and then placed on another fresh set of grain medium repeatedly until sufficient numbers of weevils of the same age are obtained for the experiments. The set up was then kept at laboratory conditions on an open air shelf. Emerged F_1 progeny 1 - 3 days old was then used for the experiments (Medugu *et al.*, 2020).

Sample Preparation

The experimental jars and maize varieties were examined, cleaned and sterilized thermally in a hot-air oven (Hot Air Circulated Oven; OV95c) at 60^{o}C for 1 hour to kill any pest and pathogen that might be present, and afterwards allowed to equilibrate for 24 hours in the laboratory (Medugu, 2012). The above preparation was carried out prior to morphological and morphometric characterization and standardization for bioassays.

Experimental Procedures and Bioassay

Morphological characteristics of maize genotypes

Ten randomly selected maize grains from each variety were carefully examined for morphological characteristics (Chinaru *et al.,* 2015). The description for each variety was based on visual observation of color, shape and texture of seed coat (Adedire *et al*., 2011). The colour of each maize grain variety were then determined using primary colour chart. The texture was felt with hand to supplement visual observation (Chinaru *et al.,* 2015).

Morphometric characteristics of maize genotypes

The Morphometric properties pertinent to the study are grain size (length, width and thickness), grain weight and grain hardness. To measure the grain size, a sample of Ten (10) grain kernels of each variety was selected randomly and their length, width and thickness measured using micrometer screw gauge (Chinaru *et al.,* 2015). For the weight of grains of each variety, 100 grains was randomly selected and weighed on digital electronic balance (Electronic Compact Weighing Scale, BL20001). For each variety the procedure was replicated 3 times.

To determine the grain hardness, 10 grain kernels from each variety was randomly selected and their hardness determined with a compression machine (model: 200063 Milano, Italy). A grain was placed at a time on the beam of the machine and the lever rolled down gradually until the grain cracks. The bearing ratio/strength value was then recorded and multiplied by a factor of 23.8 N to convert the strength value to Newton (N). The amount of force (N) needed to break the grain was then taken as a measure of grain hardness (Nwosu *et al.*, 2015).

Bioassay for Screening Maize Varieties for Relative Resistance to *S. zeamais*

Five pairs of (1 - 3 days old) adult *S. zeamais* were introduced into separate bottles containing 20 g of each maize variety weighed on a sensitive electronic balance (Electronic Compact Weighing Scale BL20001). The adult insects were then allowed to oviposit for seven days and then removed by sieving. The content of each jar were carefully returned, kept on the shelf and left undisturbed for additional 21 days. There on, the jars was then examined daily to record the emergence of F_1 adults and the adult discarded on each day. Adult count was continued until no adult(s) emerged in each jar for three consecutive days (modified after Throne and Eubanks, 2002). Each treatment was replicated three times in a completely randomized design (CRD).

Median developmental period of S. zeamais

The median developmental period (MDP) is the time (in days) from the middle day of oviposition period to 50% emergence of F_1 adults (Dobie, 1977), which is used to calculate the susceptibility index of maize grains to *S. zeamais* infestation.

Progeny production of S. zeamais

After removing all the introduced adult insects as described above, each bottle was then kept under the same experimental conditions to further assess the emergence of F_1 progeny. The number of F_1 progeny in each bottle was counted after additional 40 days. To do this, the content of each bottle was poured onto a tray and every emerging progeny was removed, counted and recorded on each assessment day.

Susceptibility index

The Dobie index of susceptibility was then used as a criterion to separate maize varieties into different resistance and susceptible groups (Dobie, 1974; 1977). The susceptibility Index is given by the formula:

$SI = \text{Log}f_1/D \times 100$.
Where: SI = Susceptibility Index;
Log F_1 = Log number of F_1 emerged adults;
D = Mean length of developmental period (days).

The Dobie Index was then used to classify the maize varieties into susceptibility groups using the scales: ≤4 = resistant; 4.1 - 6.0 = moderately resistant; 6.1 - 8.0 = moderately susceptible; 8.1 - 10 = Susceptible; >10 = highly susceptible (Dobie, 1974).

Statistical Analysis

Before analysis, data on mortality were arc-sine transformed while, data on progeny production was square root $\sqrt{(x + 0.5)}$ transformed. The transformed data were then subjected to analysis of variance (ANOVA) using the GLM procedure of Statistix 8.0 to determine differences among treatment means. Treatment means were then separated using Tukey-Kramer “Honestly Significant Difference” (HSD) test at 5% level of probability.

III. Result

Morphological characteristics of maize varieties

The varieties differed in terms of color and shape but not in appearance, face-type and texture. Two color types were differentiated (Table 1): yellow in SAMMAZ 36, SAMMAZ 37, SAMMAZ 38, Bataji and Bodeji, while white in the other varieties (Table 2). All sampled varieties were opaque in appearance, had dent or flint face and are smooth in texture, and the shapes varied from hexagonal as in SAMMAZ 13, SAMMAZ 21, SAMMAZ 22, SAMMAZ 27, SAMMAZ 30, SAMMAZ 37, SAMMAZ 38, Baleji, Bataji and Saksi; oval in SAMMAZ 15, SAMMAZ 16, SAMMAZ 20, SAMMAZ 33, SAMMAZ 34 and Bodeji while they are rectangular as in SAMMAZ 11, SAMMAZ 14, SAMMAZ 17, SAMMAZ 18, SAMMAZ 19, SAMMAZ 25, SAMMAZ 26, SAMMAZ 29 and Deneji Varieties (Table 1). Though, the most resistant varieties (SAMMAZ 16, SAMMAZ 20, SAMMAZ 25 and SAMMAZ 29) are white in colour (Table 1).

Table 1 Morphological Characteristic of Maize Varieties

Variety	Colour	Shape	Face-type	Texture
SAMMAZ 11	white	rectangular	semi dent	smooth
SAMMAZ 13	yellow	hexagonal	dent/flint	smooth
SAMMAZ 14	white	rectangular	dent/flint	smooth
SAMMAZ 15	white	oval	dent/flint	smooth
SAMMAZ 16	white	oval	flint	smooth
SAMMAZ 17	white	rectangular	flint	smooth
SAMMAZ 18	white	rectangular	dent/flint	smooth
SAMMAZ 19	white	rectangular	dent/flint	smooth
SAMMAZ 20	white	oval	flint	smooth
SAMMAZ 21	yellow	hexagonal	dent	smooth
SAMMAZ 22	white	hexagonal	dent	smooth
SAMMAZ 25	white	rectangular	flint	smooth
SAMMAZ 26	white	rectangular	dent	smooth
SAMMAZ 27	white	hexagonal	flint	smooth
SAMMAZ 29	white	rectangular	dent	smooth
SAMMAZ 30	yellow	hexagonal	dent	smooth
SAMMAZ 33	white	oval	dent/flint	smooth
SAMMAZ 34	yellow	oval	flint	smooth
SAMMAZ 37	yellow	hexagonal	flint	smooth
SAMMAZ 38	yellow	hexagonal	dent/flint	smooth
BALEJI	white	hexagonal	dent	smooth
BATAJI	yellow	hexagonal	dent/flint	smooth
BODEJI	yellow	oval	dent	smooth
DENEJI	white	rectangular	dent/flint	smooth
SAKSI	white	hexagonal	flint	smooth

Morphometric characteristics of maize varieties

The physical characteristics of maize grain varieties are presented in Table 2. Significant differences ($p<0.05$) among grain lengths of maize varieties measured were observed. The result indicates that SAMMAZ 13 had the longest grain length (1.71 mm) while SAMMAZ 27 had the shortest length (0.86 mm). The maize varieties grain width sizes do not differ significantly (Table 2) from each other. However, the biggest grain widths of 0.92 mm were observed in SAMMAZ 26 and Deneji while smaller widths (0.78) were recorded in SAMMAZ 25, SAMMAZ 27, SAMMAZ 34 and Bataji. The thickest and thinnest maize grain of 0.50 and 0.40 were recorded in Sammaz 18 and SAMMAZ 15, SAMMAZ 17, SAMMAZ 55 and Bataji, respectively, though they do not differ significantly (Table 2) from each other.

Table 3 also shows the mean grain weight of the maize varieties. The heaviest grain weight of 30.3 g was recorded in SAMMAZ 16 which did not significantly differ ($p<0.05$) from that of SAMMAZ 22, SAMMAZ 20 AND SAMMAZ 37 of 29.0, 27.7 and 28.3 g, respectively, the lightest grain weight of 16.3 g was recorded in variety Saksi which did not differ significantly ($p<0.05$) to all the other varieties except varieties SAMMAZ 11, SAMMAZ 14, SAMMAZ 16, SAMMAZ 20, SAMMAZ 21, SAMMAZ 22, SAMMAZ 27, SAMMAZ 37 AND SAMMAZ 38.

The hardest (382.20 N) maize grain variety was obtained from SAMMAZ 16 variety, while the softest (121.40 N) was from SAMMAZ 34 variety (Table 3). The results reveal that the strength of the hardest variety was not significantly ($p<0.05$) different to all the other varieties except SAMMAZ13, SAMMAZ 17, SAMMAZ 21, SAMMAZ 22, SAMMAZ 25, SAMMAZ 26, SAMMAZ 34, SAMMAZ 37, SAMMAZ 38, Bodeji and Saksi. However, the strength of the softest variety did not significantly differ to the above mentioned varieties (Table 2).

Table 2 Morphometric Characteristics of different Maize Varieties

	Size (mm)			Weight	Hardness
Variety	Length	Width	Thickness	(g/100 grains)	(N)
SAMMAZ 11	1.07^{d-i}	0.81^{a}	0.45^{a}	24.0^{d-g}	293.5^{a-f}
SAMMAZ 13	1.04^{g-j}	0.83^{a}	0.45^{a}	19.0^{hij}	245.9^{c-i}
SAMMAZ 14	0.98^{jk}	0.86^{a}	0.44^{a}	25.3^{b-e}	285.6^{a-g}

SAMMAZ 15	0.96^{k}	0.84^{a}	0.41^{a}	17.7^{ij}	285.1^{a-h}
SAMMAZ 16	1.71^{a}	0.92^{a}	0.42^{a}	30.3^{a}	382.2^{a}
SAMMAZ 17	1.05^{f-j}	0.83^{a}	0.40^{a}	19.0^{hij}	161.5^{ij}
SAMMAZ 18	1.13^{cd}	0.78^{a}	0.50^{a}	19.7^{hij}	296.6^{a-f}
SAMMAZ 19	1.12^{cde}	0.87^{a}	0.48^{a}	18.0^{ij}	296.6^{a-f}
SAMMAZ 20	1.20^{b}	0.92^{a}	0.48^{a}	29.0^{ab}	356.9^{abc}
SAMMAZ 21	0.85^{l}	0.78^{a}	0.42^{a}	21.0^{c-f}	176.9^{hij}
SAMMAZ 22	1.06^{e-i}	0.77^{a}	0.43^{a}	18.0^{ij}	245.6^{c-i}
SAMMAZ 25	1.16^{bc}	0.90^{a}	0.40^{a}	28.3^{abc}	369.9^{ab}
SAMMAZ 26	1.12^{cg}	0.87^{a}	0.45^{a}	19.0^{hij}	221.3^{e-j}
SAMMAZ 27	1.09^{d-h}	0.87^{a}	0.47^{a}	24.7^{f-i}	292.1^{a-g}
SAMMAZ 29	1.16^{bc}	0.88^{a}	0.40^{a}	27.7^{a-d}	359.9^{ab}
SAMMAZ 30	1.11^{c-f}	0.83^{a}	0.46^{a}	17.7^{ij}	340.4^{a-d}
SAMMAZ 33	0.96^{k}	0.82^{a}	0.45^{a}	19.0^{hij}	303.6^{a-e}
SAMMAZ 34	1.05^{f-j}	0.78^{a}	0.43^{a}	17.3^{ij}	121.4^{j}
SAMMAZ 37	0.99^{jk}	0.84^{a}	0.45^{a}	17.3^{ij}	195.5^{f-j}
SAMMAZ 38	1.02^{ijk}	0.84^{a}	0.43^{a}	26.7^{e-h}	187.1^{g-j}
BALEJI	1.04^{f-j}	0.80^{a}	0.44^{a}	20.7^{ghi}	191.7^{f-j}
BATAJI	1.02^{ijk}	0.78^{a}	0.40^{a}	17.3^{ij}	301.5^{a-e}
BODEJI	1.04^{hij}	0.84^{a}	0.41^{a}	16.7^{j}	267.9^{b-i}
DENERI	1.02^{ijk}	0.87^{a}	0.41^{a}	18.3^{ij}	297.4^{a-f}
SAKSI	1.06^{e-i}	0.84^{a}	0.42^{a}	16.3^{j}	245.9^{c-i}
SE±	0.01	3.30	1.78	2.91	0.80
CV	2.59	4.91	5.01	5.84	12.52
HSD $_{(0.05)}$	0.0001	0.0001	0.0001	0.0001	0.0001

Means followed by the same superscript along the column are not significantly different (P<0.05) from each other using Tukey-Kramer HSD test.

Relative Resistance of Maize Varieties to S. zeamais

The number of progeny produced by *S. zeamais* is presented in Table 4. There were significant differences (*P*<0.05) among the maize varieties in the number of progeny produced as indicated in Table 4. The highest number of progeny was counted in bottles of the varieties SAMMAZ 29 followed by SAMMAZ 20 and SAMMAZ 16 of 56.0, 54.0 and 53.3, respectively. An appreciably higher number of progeny were also recorded in varieties Baleji, Bataji and Deneji of 44.7, 42.3 and 40.7, respectively. The result also shows significantly (P<0.05) lower number of progeny was produced in most of varieties. Though, the least number of F_1 progeny in SAMMAZ 25 (26.0) differed significantly (P<0.05) to most of the varieties. However, SAMMAZ 20, SAMMAZ 29, SAMMAZ 25 AND SAMMAZ 16 had the lowest progeny of 36.0, 30.3, 30.0 and 26.0 g, respectively.

Significant differences (P<0.05) among the varieties were recorded with regard to the median developmental time (MDT) (Table 4). The MDT ranged from 26.7 to 42.0 days. *Sitophilus zeamais* reared on the varieties SAMMAZ 34, SAMMAZ 21 AND SAMMAZ 17 had relatively lower MDT of 26.7, 28.0 and 28.3, respectively which was significantly different (P<0.05) to the other varieties (Table 4). However, SAMMAZ 25, SAMMAZ 20, SAMMAZ 29, SAMMAZ 11 and SAMMAZ 16 had the highest MDT of 42.0, 40.0, 39.0, 38.3 and 38.0, respectively.

Table 4 also shows the index of susceptibility which indicates that there are significant differences (P<0.05) among the grains of maize varieties. The SI ranged from 3.4 in SAMMAZ 25 to 6.5 in SAMMAZ 34. Out of the twenty five maize varieties tested against *S. zeamais* for resistance, only four varieties; SAMMAZ 16, SAMMAZ 20, SAMMAZ 25 AND SAMMAZ 29 had index of susceptibility of 3.9, 3.9, 3.4 and 3.8, respectively and are regarded as resistant to weevil attack. However, most of the varieties do not differ significantly to each other in regard to SI as in SAMMAZ 11, SAMMAZ 13, SAMMAZ 14, SAMMAZ 15, SAMMAZ 18, SAMMAZ 19, SAMMAZ 22, SAMMAZ 26, SAMMAZ 27, SAMMAZ 30, SAMMAZ 33, SAMMAZ 37 and SAMMAZ 38. Baleji, Bataji, Bodeji, Deneji and Saksi had SI which ranges from 4.1 to 5.4 and are regarded as moderately resistant to weevil attack. Three varieties SAMMAZ 17, SAMMAZ 21 and SAMMAZ 34 had SI of 6.1, 6.2 and 6.5, respectively and are regarded as moderately susceptible to weevil attack (Table 4).

Table3 Total number of F_1 progeny emergence, median developmental time (MDT) and Susceptibility index (SI) of different maize varieties to *Sitophilus zeamais*

Variety	F_1 progeny Emerged		MDT (days)	SI	Susceptibility Status
SAMMAZ 11	36.0^{d-h}	38.3^{a-d}	4.1^{efg}	moderately resistant	
SAMMAZ 13	36.3^{d-h}	36.3^{b-f}	4.3^{c-f}	moderately resistant	
SAMMAZ 14	37.0^{d-h}	37.0^{i}	4.2^{ef}	moderately resistant	
SAMMAZ 15	37.0^{d-h}	34.7^{b-g}	4.5^{c-f}	moderately resistant	
SAMMAZ 16	30.0^{h-i}	38.0^{a-d}	3.9^{fg}	resistant	
SAMMAZ 17	53.3^{b}	28.3^{d-h}	6.1^{a}	moderately susceptible	
SAMMAZ 18	33.3^{e-i}	28.0^{hi}	5.4^{ab}	moderately resistant	
SAMMAZ 19	35.0^{d-h}	35.0^{b-g}	4.4^{c-f}	moderately resistant	
SAMMAZ 20	36.0^{d-h}	40.0^{ab}	3.9^{fg}	resistant	
SAMMAZ 21	54.0^{bc}	28.0^{ghi}	6.2^{a}	moderately susceptible	
SAMMAZ 22	34.3^{e-h}	37.7^{a-e}	4.1^{efg}	moderately resistant	
SAMMAZ 25	26.0^{i}	42.0^{a}	3.4^{g}	resistant	
SAMMAZ 26	30.7^{ghi}	35.3^{b-g}	4.2^{def}	moderately resistant	
SAMMAZ 27	39.0^{c-f}	36.3^{b-f}	4.4^{c-f}	moderately resistant	
SAMMAZ 29	30.3^{ghi}	39.0^{abc}	3.8^{fg}	resistant	
SAMMAZ 30	33.0^{f-i}	36.3^{b-f}	4.2^{efg}	moderately resistant	
SAMMAZ 33	34.7^{e-h}	31.3^{f-i}	4.9^{bcd}	moderately resistant	
SAMMAZ 34	56.0^{a}	26.7^{c-g}	6.5^{a}	moderately susceptible	
SAMMAZ 37	35.9^{d-h}	33.7^{c-g}	4.6^{c-f}	moderately resistant	
SAMMAZ 38	35.7^{d-h}	32.3^{e-h}	4.8^{b-e}	moderately resistant	
BALEJI	44.7^{bc}	34.0^{e-h}	4.9^{bcd}	moderately resistant	
BATAJI		42.3^{bcd}	35.7^{c-g}	4.6^{c-f}	moderately resistant
BODEJI		37.7^{c-g}	34.7^{b-g}	4.5^{c-f}	moderately resistant
DENERI		40.7^{cde}	34.7^{b-g}	4.6^{c-f}	moderately resistant
SAKSI	34.3^{e-h}	34.0^{c-g}	4.5^{c-f}	moderately resistant	
SE±	0.12	0.98	0.15		
CV	3.32	4.88	5.66		
$HSD_{(0.05)}$		0.0001	0.0001	0.0001	

Means followed by the same superscript along the column are not significantly different (P<0.05) from each other using Tukey-Kramer HSD Test. MDT = Median developmental time; SI = Susceptibility index.

IV. Discussion

Considerable variation was found among the maize varieties with respect to F_1 progeny, median developmental time, and the susceptibility index. The differences in the resistance of the maize varieties indicate the inherent ability of a particular variety to resist *S. zeamais* attack. Resistance in stored maize to insect attack has been attributed to the presence of some morphological, physical and chemical factors (Dobie, 1974; Tepping *et al*., 1988) or non-nutritional factors, especially phenolic compounds (Serratos *et al*., 1987). These factors acting alone or in combination are responsible for the varying levels of resistance to certain species of storage insect pests (Chandrashekar and Satyanarayana, 2006). Bamaiyi *et al*. (2007) also reported grain hardness as the main resistance parameter against *S. oryzae* in stored sorghum. Goftishu and Belete (2014) noted that Progeny emergence was highly correlated with the susceptibility of varieties to weevil infestation. Consequently, varieties which are susceptible to maize weevils produce more number of progeny as compared to the resistant varieties. The large difference in the number of F_1 progenies produced among the resistant and susceptible varieties is an important variable that underscores the effect of resistant varieties for the management of *S. zeamais* in stored maize.

Out of the twenty five maize varieties tested against *S. zeamais* in this study, only three varieties (SAMMAZ 17, SAMMAZ 21 and SAMMAZ 34) were susceptible. The remaining twenty two varieties were resistant. Relatively longer developmental time was required on the resistant varieties, than on the susceptible varieties. Similarly, weevils on varieties having a high index of susceptibility displayed reduced periods for the completion of developments. Reduced survival and establishment will reduce the insect populations and the resultant crop damage. Prolongation of development periods will also result in reduction of number of generations in a season. According to Horber (1988) and Abebe *et al.* (2009) the index of susceptibility is based on the assumption that the more F_1 progeny and the shorter the duration of the development, the more susceptible the grains would be.

Several maize varieties, including local land races, have been characterized as sources of resistance to *S. zeamais* (Giga and Mazarura, 1991; Arnason *et al.*, 1994) similarly, the present study found some local cultivars, such as Baleji, Bataji, Bodeji, Daneji and Saksi to show resistance to *S. zeamais.* The difference in maize varieties in this study was mainly due to the variation in F_1 progeny emergence, median developmental time (MDT) and susceptibility index. These variations in the differential susceptibility of the varieties show the innate capacity of particular varieties to resist *S. zeamais* attack. Resistant varieties exhibited reduced multiplication of F_1 progeny, longer median developmental period and lower score of susceptibility index. A number of factors contribute to the differences in genetic resistance of varieties to stored grains insects attack through their influence on fecundity and development (Adetunji, 1998). This indicates that presumably antibiosis and/or antixenosis (Non-preference) mechanism of resistance play a role in the varietal resistance. Similarly, several authors reported that antibiosis and non-preference act together as mechanisms of resistance to *S. zeamais* in maize grains (Torres *et al.,* 1996; Chuch-Hernandez *et al*., 2013; Temesgen and Waketole, 2013).

Sitophilus zeamais require less developmental time on the susceptible varieties, while longer developmental time was elapsed on the resistant varieties. This indicates that one effect of increased resistance is prolongation of the developmental period which has negative effect on population growth and consequent damage. Similarly, *S. zeamais* emerged from varieties having a high index of susceptibility exhibited reduced periods for the completion of developments. Horber (1988) observed that, the higher the number of F_1 progeny produced and the shorter the duration of the development, the more susceptible the varieties would be. According to Abraham (1991), the extent of damage during storage depends on the number of emerging adults during each generation and the duration of each developmental time. Thus, varieties allowing rapid and high levels of adult emergence will be more seriously damaged.

V. Conclusion And Recommendations

The information obtained from the present study will assist to devise the management strategies against this legendary pest of maize as well as other cereals. Resistant varieties can reduce the cost of weevil management and can also be utilized as an environmental friendly way to reduce damage by *S. zeamais.* In the past, a reasonable number of maize varieties have been evaluated for their resistance to maize weevil, but still more explorations are needed to achieve long-term and sustainable pest management strategies and to diversify the basis of resistance to this pest.

The contributions of shape and face-type to grain resistance were not clear and therefore merit further investigation. It is necessary that factors which influence susceptibility such as grain hardness to be elucidated so as to provide more information to maize breeders. Therefore only the resistant varieties should be stored for longer period. Finally, this research work has provided reliable information on important inherent maize characteristics that confer resistance that can be used as a promising integrated management strategy for *S. zeamais* in stored maize grains.

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