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PROXIMATE COMPOSITIONS AND GRAIN WEEVIL (*S. ZEAMAIS* MOT.) RESISTANCE IN STORED MAIZE.

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ABSTRACT

An experiment was conducted at the Department of Crop Science, University of Nigeria, Nsukka to evaluate seventeen maize varieties (Sammaz – 11, 14, 15, 16, 17, 18, 20, 26, 27, 28, 29, 31, 32, 33, 34, 35 and 37) developed at Institute for Agricultural Research (IAR) in collaboration with International Institute for Tropical Agriculture (IITA) and three accessions (ENU-E, NSU-P, and KAG-W) sourced locally. The experiment was laid out in completely randomized design (CRD), with three replications. The result showed there were wide variations in the proximate contents which influenced their susceptibility to S. zeamais.. Sammaz – 32 had the least susceptibility index (SI) of 1.79 and was classified as resistant. ENU-E, NSU-P, KAG-W, Sammaz – 11, 14, 15, 16, 20, 26, 27, 28, 29, 31, 34 and 37 were classified as moderately resistant as their SI ranged between 2.6 and 5.0, while Sammaz – 17, 33 and 35 were classified as moderately susceptible with a susceptibility index of between 5.6 and 7.5. Correlation results showed a negative significant correlation (r = -0.255*, n = 20, P < 0.05) between grain moisture and susceptibility index. On the other hand, a positive significant correlation (r = 0.278*, n = 20, P < 0.05) was established between susceptibility index and carbohydrate. Other proximate compositions however did not attain any significant correlation status with susceptibility index. Path coefficient analysis revealed that %grain moisture (%H_20) (-0.4174) had the highest direct negative effect followed by % fat (-0.3698) on susceptibility index (SI). The total correlation of %grain moisture (-0.255*), though low but significant with two opposing positive indirect effects from % fat (0.1298) and % fibre (0.0764), while the total correlation of fat (-0.109) had opposing indirect positive effects from % H_20 (0.1465), % protein (0.1647) and % Ash (0.0714). The correlation studies and path coefficient analysis indicated prospects for the improvement of the maize accessions/varieties through selection of the two traits (percentage grain moisture and percentage fat) for resistance against maize weevil attack.

Keywords: Proximate contents, *Sitophilus zeamais*, accessions, susceptibility index, correlation studies, path coefficients.

INTRODUCTION

Maize is an important subsistence and cash crop. After wheat and rice, maize is the third most grown cereal in the world (Issa, *et al.,* 2011). Maize is however attacked by insect pests prior to harvest and storage (Caswel, 1961; Muyinza, 1998 and Demissie *et al.*, 2008). The pests include the maize weevil (*Sitophilus zeamais* Mot.) (Coleoptera: Curculionidae), which could be the most predominant and destructive (Issa, *et al.,* 2011). The maize weevil is an important pest especially on maize stored in the field for both food and seed (Thanda and Kevin, 2003), and can cause weight loss of stored grain from 20 - 90% for untreated maize (Issa, *et al.*,2011).

Synthetic chemicals are easily and commonly used as control measures by most farmers to reduce storage losses caused by insect pest (Pereira et al., 2009). However, some of the challenges associated with insecticide application include: toxic residues in food, environmental pollution, adverse effects on beneficial and non-target insects, increased risk to workers safety, insect developing resistance against insecticides (Pereira et al, 2009) and the high cost of the chemicals which render them unattractive for the management of these

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insect pests on the field or store (Issa *et al.,* 2011). It is therefore important to develop cheap and effective methods of reducing *S. zeamais* such as the breeding of resistant varieties in most areas with limited resources where the maize weevil is reported to be of economic importance. (Danho *et al.,* 2002). The objective of this study was to determine the level(s) at which maize accessions / varieties may confer resistance to maize accessions against *S. zeamais* attack so that they can be improved upon by breeders to produce resistant ones through selections, though Ivbijaro (2009) stated that resistant maize cultivars can reduce losses due to weevil infestation but no maize grain was immuned to attack by the weevil.

MATERIAL AND METHODS

Culture of *S. zeamais*

A culture of *S. zeamais* was established to supply freshly emerged weevils for the experiments. About 10 kg seeds of a white local accession from Kagoro in Kaduna State were procured and cleaned to remove seeds with visible damaged symptoms. The cleaned seeds were fumigated with phostoxin tablet in an air tight container at the rate of two tablets / 50 kg grain weight (Amadioha *et al.,* (2004). The fumigated seeds were left in the air-tight poly-ethylene bag for four days and there after aired for another four days before use (Dasbak *et al.,* 2009). The seeds were then transferred into four plastic buckets of four litres capacity each and kept in the Department of Crop Science Laboratory under environmental conditions of 26±3^{0}C and 65-90 % R.H for one week. Unsexed adult *S. zeamais* weevils of between one and fifteen days were collected from infested maize grains in the laboratory and cultured on the cleaned and disinfested maize grains (Kagoro-white) in the four plastic buckets. Each bucket containing three kg grains was infested with about 150 weevils. The buckets were covered with muslin cloth and fixed with a rubber band to allow aeration and to prevent escape of weevils. Seven days after oviposition, all the weevils were removed from each bucket by sieving and the emergent adults (at 36-38 days after oviposition) were harvested and used to infest each maize accessions / varieties in the screening test to determine the susceptibilities to *S. zeamais*.

Screening the maize varieties for susceptibility/resistance to *S. zeamais*

Maize seeds (100 g) from each of the maize accessions / varieties were placed in 500 ml plastic containers with fine mesh perforations at opposite sides allowing for ventilation and preventing escape of the weevils. The no choice test method, in which the weevils were introduced into each sample of seeds, were as follows: Twenty newly emerged unsexed adult weevils were introduced into the buckets to infest the 100 g seeds of each accession / variety and were kept for seven days for oviposition as reported by Abebe (2009) and Derera *et al*. (2001). Seeds of each accession / variety without *S. zeamais* were kept under similar conditions to serves as a control. The treatments were arranged in a Complete Randomized Design (CRD) with three replications on the laboratory slabs for observation at 26-29^{0}C, 65-90 % relative humidity.

a. Susceptibility Index (SI)

The index of susceptibility (SI) of each maize variety / accession to weevils was calculated using the method of Howe, (1971); Dobie, (1974); Gharib, (2004); Dasbak *et al*., (2009)*;* Abebe, (2009). SI was determined by finding the log of the total number of emerged adults divided by the median development time from egg to adult multiplied by 100 as follows:

$$\text{Susceptibility Index (SI)} = \frac{\text{LogS}}{\text{T}} \text{ x } 100$$

Where:

Log S = Logarithm of total number of adult emergence

T = Median Development Time (in days).

100 = percentage (%)

The values of susceptibility indices were categorized into five ranks according to Mensah (1986) as follows:

a. Accessions with values between 0.0-2.5 were considered resistant (R)
b. Accessions with values between 2.6-5.0 were considered moderately resistant (MR)
c. Accessions / varieties with values between, 5.1-7.5 were considered moderately susceptible (MS)
d. Accessions / varieties with values between 7.6- 10.0 were considered susceptible (S)
e. Accessions / varieties with S1 values greater than 10.0 were considered highly susceptible (HS)

b.

c. Design and Analysis Employed

The determination of SI for all accessions / varieties were carried out in the laboratory using Complete Randomised Design (CRD). The data collected were subjected to Analysis of Variance procedure using Genstat statistical package 14th Edition and mean differences were compared by the use of F-LSD as outlined by Obi (2002). Correlation matrix was performed between all the variables assayed. Cause and effect relations of the variables in time and space were determined using path coefficient analysis (Dewey & Lu, 1959) on percentage moisture, percentage fat, percentage ash, percentage protein, percentage carbohydrate and percentage fibre as some of the major proximate factors of maize grain susceptibility to *S. zeamais* attack.

Proximate composition of different accessions / varieties of maize

The proximate composition of different accessions of maize is presented in Table 1. The percentage moisture content (3.84 %) in Sammaz-27 was significantly ($p<0.05$) higher than in other

accessions / varieties. The least moisture content (2.18 %) was recorded in Sammaz-29. The highest percentage fat (4.18 %) was recorded in Sammaz-32 followed by Sammaz-26 which recorded 4.10 % fat. The two accessions / varieties were significantly ($p>0.05$) similar but both differed significantly ($p<0.05$) from other accessions / varieties in percentage fat content. The least percentage fat (3.14%) was recorded in Sammaz-16 and a general mean of 3.65 % fat was recorded for all maize accession / varieties. Sammaz-16 and 34 had significantly ($p>0.05$) similar percentage ash content of (2.04 %) which were significantly ($p<0.05$) different and higher than those of other accessions / varieties. The least, ash content of 1.12 % was recorded in Sammaz-35, which was significantly ($p<0.05$) different and lower than in other accessions / varieties. The percentage protein (8.76 %) recorded in Sammaz-37 was the highest and it was significantly different ($p<0.05$) from other maize accessions / variety. The least percentage protein (7.10 %) was recorded in Sammaz-14. Percentage carbohydrate formed the largest part of the grain of each maize accession / varieties. The highest percentage carbohydrate of 85.36 % was recorded in Sammaz-17 followed by 85.16 % in Sammaz-29. Both accessions / varieties differ significantly ($p<0.05$) from each other. The least percentage carbohydrate mean (82.44 %) was recorded in NSU-P and Sammaz-37. Sammaz-15 showed the highest (3.82 %) percentage fibre content which was significantly ($p<0.05$) different from other accessions / varieties. Sammaz-26 recorded the least percentage fibre content of 1.16 % which differed significantly ($p<0.050$) from other accessions / varieties.

RESULTS

Correlation matrix of susceptibility index of *S. zeamais* against proximate qualities of maize

The correlation studies (Table 2) on six proximate qualities namely moisture, carbohydrate, lipids, proteins, fibre and ash showed that susceptibility index (SI) had a significant and positive correlation with carbohydrate ($r=0.278^{*}$). A significant negative correlation existed between susceptibility index and moisture ($r = -0.255^{*}$). Moisture had highly significant positive correlations with fibre ($r = 0.381^{**}$) and ash ($r =0.413^{**}$) but showed a significant negative correlation with protein ($r = -0.294^{*}$) and a highly significant negative correlation with fat ($r = -0.365^{**}$). A highly significant positive correlation existed between fat and protein ($r = -0.883^{**}$) while the correlations of fat with fibre ($r = -0.399^{**}$) and ash ($r = 0.442^{**}$) were negative and highly significant. Highly significant negative correlations existed between protein and fibre ($r = - 0.358^{**}$) and ash ($r = -0.477^{**}$). Fibre had a highly significant and positive correlation with ash ($r = 0.515^{**}$).

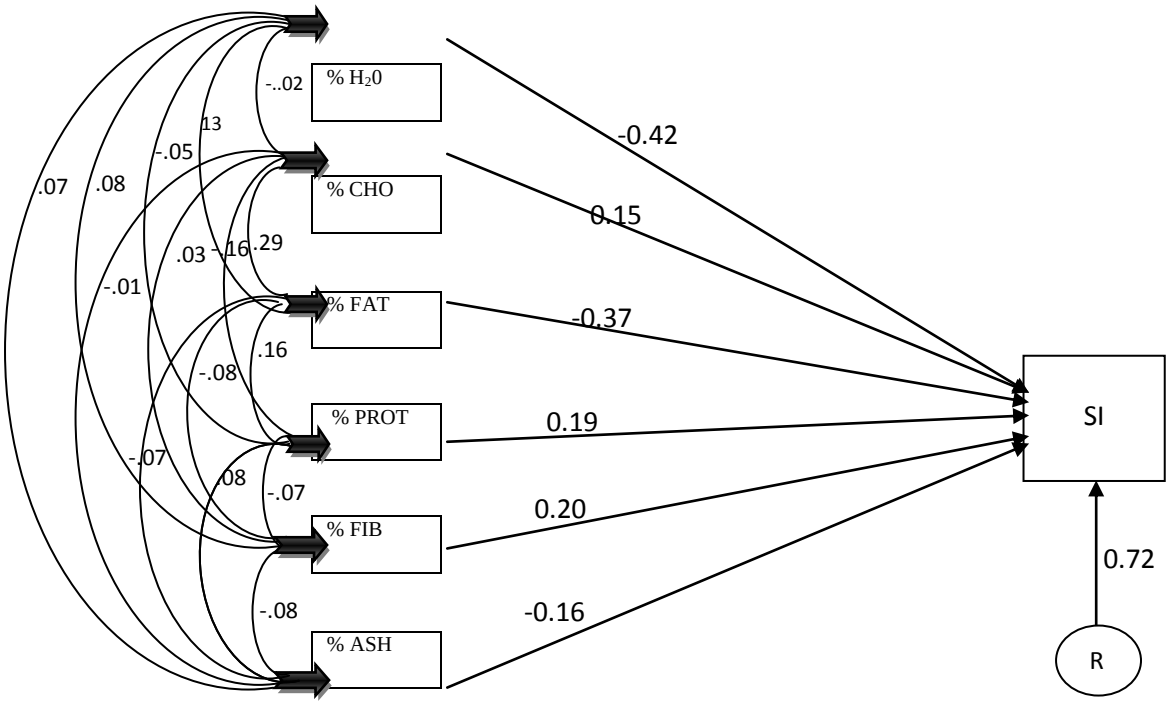

Figure 1: Path diagram and coefficients of the proximate properties of maize accessions / varieties and their effects on the usceptibility index

% H_20 = percentage water (moisture),% CHO = percentage carbohydrate,% FAT = Percentage fat, % PROT = Percentage protein, % FIB = Percentage Fibre, % ASH = Percentage Ash, SI = Susceptibility index, R = Residual

Table 1: Proximate composition of different accessions / varieties of maize

VARIETY	% MOISTURE	% FAT	% ASH	% PROTEIN	% CHO	% FIBRE	SUSCE. INDEX (SI)	SUSCE. STATUS (ST)
ENU-E	3.14	3.74	1.28	8.12	83.72	3.48	4.57	MR
KAG –W	3.12	3.78	1.28	8.16	83.66	2.78	4.57	MR
NSU-P	3.12	4.08	1.64	8.72	**82.44**	2.73	3.47	MR
SAM-11	3.26	3.38	1.46	7.64	84.80	2.64	4.67	MR
SAM-14	3.12	3.68	1.40	7.10	84.16	2.16	4.10	MR
SAM-15	3.42	3.18	1.26	7.56	84.58	2.48	4.13	MR
SAM-16	3.74	**3.14**	**2.04**	**6.74**	84.34	**3.82**	4.11	MR
SAM-17	3.14	3.44	1.26	6.80	**85.36**	2.14	5.06	MS
SAM-18	3.16	3.24	1.72	7.14	84.74	3.68	3.66	MR
SAM-20	3.40	3.22	1.42	7.46	84.50	2.56	4.16	MR
SAM-26	3.16	4.10	1.18	8.66	82.90	**1.16**	3.47	MR
SAM-27	**3.84**	3.68	1.44	7.58	83.46	3.42	3.72	MR
SAM-28	2.96	3.74	1.18	8.70	83.42	2.18	4.40	MR
SAM-29	**2.18**	3.76	1.24	7.66	85.16	2.18	4.83	MR
SAM-31	3.12	3.82	1.26	8.40	83.40	3.18	3.50	MR
SAM-32	3.26	**4.18**	1.22	8.64	82.70	2.18	**1.79**	R
SAM-33	3.48	3.26	1.66	7.16	84.44	2.48	**5.84**	MS
SAM-34	3.37	3.46	**2.04**	7.44	83.32	2.56	3.55	MR
SAM-35	3.26	3.98	**1.12**	**8.76**	82.88	2.12	5.33	MR
SAM-37	3.12	4.08	1.64	8.72	**82.44**	2.72	4.63	
MEAN	3.22	3.65	1.44	7.86	83.82	2.63	4.03	
F.LSD(0.05)	0.04	0.02	0.02	0.02	0.02	0.02	0.91	
Fpr	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	<0.001	

ENU-E = Enugu Ezike, KAG-W = Kagaro- white, NSU-P = Nsukka-pink, SAM = Sammaz, F-LSD = Fisher's least significant difference

Table 2: Correlations matrix of susceptibility index of *S. zeamais* against proximate ualities of maize

	Susceptibility index (SI)	% H_20	% CHO	% Fat	% protein	% fibre	% Ash
Susceptibility index (SI)	1	-.255*	.278*	-.109	-.094	.001	-.184
% H_20		1	-.132	-.365**	-.294*	.381**	.413**
% CHO			1	-.782**	-.844**	.136	.037
% Fat				1	.883**	-.399**	-.442**
% protein					1	-.358**	-.477**
% fibre						1	.515**
% Ash							1

Note: **.Correlation is significant at the 0.01 level (2 – tailed)
.Correlation is significant at the 0.05 level (2 – tailed)
n = number of treatments (20)

Direct and indirect effects of the proximate contents of maize on susceptibility index (SI) to *S. zeamais* Mot.

The result in Table 3 of the path coefficient analysis of six proximate contents of maize accessions / varieties showed that fibre (0.1981) exerted maximum direct positive effects on susceptibility index (SI). It also recorded positive indirect effects through fat (0.1478) and carbohydrate (0.0202) while indirect effects through ash (-0.0829), protein (-0.0668) and fibre (-0.1610) were negative. Protein recorded positive direct effect (0.18650) and positive indirect effects on susceptibility index through ash (0.0770), moisture (0.1204) and negative indirect influence through percentage fibre (-0.0710), fat (-0.3265) and carbohydrate (-0.1251). Carbohydrate (0.1482) had a positive direct effect on susceptibility index and indirect positive influence through fibre (0.0270), fat (0.2894), moisture (0.0602) and negative indirect influence through ash (-0.0060) and protein (-0.1574). Moisture (-0.4174), exerted direct negative and indirect negative effects through fat (-0.3698) and ash (-0.1610) influence on susceptibility index. The residual factor recorded was 0.72, which indicated that 28 % of the proximate traits that affect susceptibility index were covered in the study.

Table 3: Path Coefficient Analysis showing the direct and indirect effects of the proximate contents of maize on susceptibility index (SI) to *S. zeamais* MOT

Variables	Variables						
	$\%H_20$	%CHO	%FAT	%PROT	% FIB	%ASH	Corr. Coeff.
$\%H_20$	**-0.4174**	-0.0214	0.1298	-0.0538	0.0764	-0.0670	-0.255*
%CHO	0.0602	**0.1482**	0.2894	-0.1574	0.0270	-0.0060	0.278*
% FAT	0.1465	-0.1160	**-0.3698**	0.1647	-0.0792	0.0714	-0.109
%PROT	0.1204	-0.1251	-0.3265	**0.1865**	-0.0710	0.0770	-0.094
%FIB	- 0.1610	0.0202	0.1478	-0.0668	**0.1981**	-0.0829	0.001
%ASH	-0.1737	0.0055	0.1639	-0.0891	0.1020	**-0.1610**	-0.184
Residual (R)							0.7219

The dependent variable is Susceptibility Index (SI)
Figures in bold prints are the direct effects.
$\%H_20$ = Percentage water (moisture)
%CHO = Percentage carbohydrate
%FAT = Percentage fat
%PROT = Percentage protein
%FIB = Percentage fibre
%ASH = Percentage Ash
N = Number of treatments (20)

DISCUSSION

The experiment has shown wide variations in proximate qualities among maize accessions / varieties. Among the accession Sammaz-32 showed the highest resistance to *S. zeamais* and contained the highest percentage fat (4.10%) which differed significantly ($p>0.05$) from all other accessions/varieties. This high fat content might have been responsible for the level of resistance to *S. zeamais* shown by the accession / variety which agreed with the report of Gharib (2004) that resistance of cereal varieties to grain moth infestations was due to high amounts of lipid. The correlation matrix showed that the susceptibility indices to *S. zeamais* correlated negatively with % fat (-0.109) and % protein (-0.094) which agreed with Tongjura *et al*. (2010), that there was a negative correlation between protein and beetle attack. The low and significant negative correlation of susceptibility index to *S. zeamais* with moisture (-0.255*) did not agree with the report of CIMMYT (2001) who reported that high moisture content make grains softer and susceptible to weevil damage. Carbohydrate (0.278*) exhibited a significant positive correlation with susceptibility indices to *S. zeamais*. These findings have shown that proximate contents of maize grains influence their resistance to *S. zeamais* which did not concur with the report of Tongjura *et al.* (2010) that the nutrient content of the maize variety did not modify its resistance to weevil infestation. Tongjura *et al.,* (2010) went further to report that the number of F_1 adult insects recorded in each maize variety did not vary according to the variation in the nutrient content of the maize studied in a correlation analysis which showed no relationship between nutrition and development of insect pest ($p>0.05$). The path analysis values showed that all proximate contents of maize had low direct positive effects except percentage moisture (-0.4174), percentage fat (-0.3698) and percentage Ash (-0.1610) which showed moderate and low direct negative effects respectively on maize grain susceptibility to *S. zeamais* , attack.

In a similar experiment, Nwankwo *et al*. (2014) had a correlation analysis which indicated strong and positive significant relationship between total *S. zeamais* adult population emergence and carbohydrate content ($r = 0.0506^*$, $p<0.05$), percentage weight loss and carbohydrate ($r = 0.503$, $p<0.05$). However there were negative and significant correlations between percentage grain damage and protein content ($r = -0.530$, $p<0.05$). percentage moisture (-0.4174), fat (-0.3698) and Ash (-0.1610) should be considered together in any breeding programme through selection for resistance of the accessions / varieties to *S. zeamais* due to their negative direct effects on susceptibility index .

CONLUSION

From the study, percentage moisture, fat, protein and ash correlated negatively with susceptibility index (SI). These should be characters of interest to maize breeders for resistance against weevil attack. Percentage moisture had low but significant ($p<0.05$) negative correlation with susceptibility index (SI), but cannot be considered for improvement against weevil resistance to maize in the store, because moisture could attract pathogens. The path coefficients indicated that fat had a moderate direct negative effect on SI and could be used by breeders in the selection of the maize accessions / varieties for improvement against *S. zeamais* attack.

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