INVESTIGATING THE SUSCEPTIBILITY TO INFESTATION OF SOME NEWLY INTRODUCED GHANIAN MAIZE VARIETIES TO *SITOPHILUS ZEAMAIS* Motschulsky (Coleoptera, Curculionidae)

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Abstract: Grains of seven newly introduced maize varieties and three local varieties were analyzed in the laboratory for their susceptibility to infestation by the maize weevil, *Sitophilus zeamais*. Kawanzie was the least susceptible and Pool 16 SR the most susceptible. Gandajika 8149 and Dobidi did not differ significantly (at P = 0.05) from Kawanzie in susceptibility to infestation by *S. zeamais*. However, the three local varieties namely H o Local Two, H o Local One and Pokoase Local were more susceptible to infestation than Kawanzie. Significant differences in susceptibility were not observed (at P = 0.05) between Pool 16 SR and the three local varieties Composite 4, Aburotia CRI, and Dobidi. Seed viability declined as the number of adult emergence holes increased on the seeds. Fat, carbohydrate, phosphorus, iron, ash, calcium, or protein contents of the grains of the different varieties studied had no significant correlation (P = 0.5) with their susceptibilities to *S. zeamais* infestation.

Résumé: Des grains de sept variétés de maïs nouvellement introduites au Ghana et de trois variétés locales ont été analysés en laboratoire en vue de déterminer leur sensibilité au charançon du maïs, le *Sitophilus zeamaïs*. On a constaté que Kawanzie était la variété la moins sensible, Pool 16SR la plus sensible à l'infestation et qu'il n'y avait pas de différence significative de sensibilité entre Kawanzie d'une part et Pool 16EV85, Gandajika 8149 et Dobidi, d'autre part. Les trois variétés locales, à savoir H o Local Two, H o Local One, et Pokoase Local se sont avérés plus sensibles à l'infestation que Kawanzie. On n'a pas observé de différence significative de sensibilité (à P = 0,05) entre Pool 16SR, les trois variétés locales, Composite 4, Aburetia CRI, et Dobidi. La viabilité des semences diminue à mesure que s'accroît le nombre de trous signalant l'émergence des insectes adultes sur les graines. Enfin, il n'as pas été constaté de corrélation significative entre les teneurs en graisses, hydrates de carbones, phosphore, fer, cendres, calcium ou protéines des grains des différentes variétés étudiées et la sensibilité de ces variétés à l'infestation par le charançon du maïs, *S. zeamaïs*.

Maize (*Zea mays* L.) is a staple food for more than 40% of the population of Ghana (Prempeh, 1971). A food crop used by almost all ethnic groups for various products, it contributes to the carbohydrate and protein base of food of its consumers. In 1962, the National Food and Nutrition Survey found that it provided 90-95% of the total calories in the diet of the people on the coastal plains. The crop is a source of income to a large proportion of the farming population. The amount of land used for its cultivation each farming season is greater than any food crop. Maize has received the biggest financial assistance from the government in the past and continues to occupy a strategic position in the current government's agricultural policy. Between 90 and 95% of the annual output is used for human consumption and 5 to 10% for poultry and livestock (Quartey, 1980).

The country's population recorded an annual growth of 2.6% since the 1970 population census, resulting in the provisional figure of 12.2 million in 1984. Various measures have been adopted to increase the production of maize to feed this ever-increasing population. This includes improved husbandry methods and the introduction of high-yielding varieties, which generally display advantageous pre-harvest agronomic characteristics much better than the local varieties. Some of these characteristics include reduced growth periods, resistance to the maize streak virus and other pathogens, ability to withstand high population per unit area without lodging, uniform cob height and size, favourable plant height, etc. Unfortunately, these varieties have been reported to be susceptible to pre-harvest infestation by the *Sitophilus* spp., mainly *S. zeamais*. This leads to poor storability in relatively shorter periods.

Sitophilus zeamais has been identified as the most important primary pest of stored maize in Ghana. It can cause about 35% grain damage within less than eight weeks of storage in the Ewe barn of most small-scale farmers (Rawnsley, 1969). The extent of maize losses due to this pest could pose a hunger threat in the near future, as these small-scale farmers produce over 70% of the country's maize requirements. As new high-yielding maize varieties are being introduced for cultivation, it is necessary to consider to what extent their grains are susceptible to attack by *S. zeamais* in storage against three local varieties and also to determine some inherent factors within the grains of these varieties which could be linked to their susceptibilities.

Materials and Methods

The names and characteristics of the seven newly introduced varieties studied and the three local varieties are:

New varieties

Name	Characteristics
Pool 16 EV 85:	White dent open-pollinated variety. Plant height 165-170 cm, 95 days of maturity and 47-49 days to 50% silking. Grown in all ecological zones.
Composite 4:	White dent, open-pollinated variety. Plant height 210-220 cm, 120 + days to maturity, and 60 days to 50% silking. Grown in all ecological zones.
Gandajika 8147:	White dent, open-pollinated variety. Plant height 105-170 cm, 105 days of maturity and 51-53 days to 50% silking. Grown in all ecological zones.
Pool 16 SR:	White dent, open-pollinated streak-resistant variety. Plant height 160-165 cm, 95 days of maturity and 45-47 days to 50% silking. Grown in all ecological zones.
Kawanzie:	Yellow flint, open-pollinated variety. Plant height 160-165 cm. 95 days of maturity and 45-47 days to 50% silking. Grown in all ecological zones.
Dobidi (Ejura (1) 7843:	White dent open-pollinated variety. Plant height 200-210 cm. 120 days of maturity and 55-58 days to 50% silking. Grown in all ecological zones.
Aburotia (Tuxpeno P.B. C16):	White dent open-pollinated variety. Plant height 150-155 cm. 105 days to maturity and 51-53 days to 50% silking. Grown in all ecological zones.

Local varieties

Name	Characteristics
Pokoase Local:	White dent traditional variety. Plant height 200-205 cm. 120 days of maturity and 60 days of 50% silking. Grown mainly in Guinea Savanna zones.
H o Local One:	White flint floury traditiona variety. Plant height 200-205 cm. 120 days of maturity and 60 days to 50% silking. Grown mainly in Guinea Savanna.
H o Local Two:	White flint/dent floury traditional variety. Plant height 200-210 cm. 120 days of maturity and 58 days to 50% silking. Grown in Guinea Savanna.

The ten maize varieties were planted in a randomized complete block design with four replications. Each plot was made up of ten 20 m long rows. Spacing between rows was 0.90 m long and 0.4 cm between hills. Two grains were planted per hill. The maize was planted on 18 July and harvested 12 December 1988. The recommended cultural practices were followed (Anon, 1988). No insecticide was applied while the maize was growing.

Cobs of uniform height and size were harvested into paper bags and taken to the laboratory. The cobs were desheathed and hand-shelled and the grains fumigated "Phostoxin" in a large PVC storage tank for three days. The varieties were then removed and dried in an oven at 50° C for seven days to disinfest any mites that did not die after fumigation (Nwana and Akibo-Betts, 1982). The moisture content of the maize varieties was adjusted to 13.0% wet basis before the experiment. Laboratory temperatures during the experimental period ranged between 26-30° C and relative humidity at 09.00 hours GMT ranged between 75-85% at 15.00 hours.

Varietal Susceptibility

Three trials were conducted to determine the Susceptibility Index. Each variety was replicated six times in every trial. The method described by Dobie (1974) was used. Two hundred adult *S. zeamais* were collected and reared on a susceptible variety Hi-lysine in five 1000 cm^3 Kilner jars to raise cultures for the experiments. The sex of individual adults was determined from the form of rostrum as described by Halstead (1962) and the species was subsequently determined as *Sitophilus zeamais* Motschulsky using characters by Halstead (1964). The adults were conditioned to the different maize varieties before the actual experiments by infesting 50 g of each test sample with 16 females and eight males for seven days. The insects were altogether conditioned to each test variety in six replications. Conditioning was necessary to eliminate any short-term changes in behaviour associated with the change of the host variety (Dobie, 1974). After the conditioning period, fresh 50 g unbroken sound grain samples of the different varieties in six replicates were set up, using eight females and four males from the conditioning replicates. The insects were kept on the test samples for seven days and removed. The sex of any insect that died during this period on the test sample was determined; then it was replaced using insects from the conditioning replicates. Thus the adult insects used for the tests were 7-14 days old. The top of the Kilner jars was covered with a fine nylon mesh to allow adequate ventilation. The maize was left undisturbed until emergence began. Daily counts of F1 were made until the 66th day when all the F1 generation could be expected to have emerged.

$$\text{The Index of Susceptibility} = \frac{\text{Loge F1} \times 100}{\text{D}}$$

was computed where F1 is the total number of adults and D is the median development period, which was estimated as the time from the middle of oviposition to the emergence of 50% of the F1 generation.

Effect of S. zeamais on Viability

Sixty, forty, twenty, and ten seeds with 0, 1, 2, and 3 emergence holes respectively for each variety in the test samples were soaked in 10 cm petri dishes overnight. They were removed and placed on moistened Whatman 1 filter paper and seed germination was observed after seven days. The relationship between emergence holes and seed germination was determined.

Effect of Proximate Composition on Susceptibility

Proximate analyses of the maize varieties were carried out. This was done in order to find out if there was any correlation between the various chemical components of the grains with susceptibilities. As moisture content determined by the Burrows Digital Moisture Computer 700 was uniform (13.0% wet basis); it could not be responsible for any differences in susceptibilities. The following analyses were carried out:

Protein: Nitrogen content (N) determined on 2 g sample of macro Kjeldahl method and percentage protein calculated by multiplying N with the factor 6.25.

Fat: Extracted from 5 g sample by Soxhlet continuous extraction method for about 6 hours.

Carbohydrate: Determined by subtracting the sum of moisture, protein, and fat contents from 100.

Ash: 5 g sample heated in a silica crucible on a burner in a fume cupboard and later ashed in an electric muffle furnace at 550° C.

Phosphorus: Determined in accordance with the method described by Fogg and Wilkinson (1958).

Iron:	Determined by 2-2' dipyridyl method as described by AOAC (1970).
Calcium:	Determined by the standard method by AOAC (1970).

Results: Varietal Susceptibilities

The Susceptibility Indices obtained for the ten maize varieties studied are shown in Table 2.

Table 1. Susceptibility Indices of 10 Maize Varieties

Maize variety	No. of F1	Development Period	Susceptibility Index
Kawanzie	21	34.05	8.00 a
Pool 16 EV 85	19	31.75	8.19 ab
Gandajika 814-9	30	33.70	10.13 abc
Dobidi	52	32.60	10.41 abcd
Aburotia CRI	45	32.10	10.63 bcd
H o Local Two	39	33.53	11.32 cd
H o Local One	40	33.85	11.39 cd
Composite 4	42	32.35	11.54 cd
Pokoase Local	56	31.70	12.61 d
Pool 16 SR	53	30.70	13.02 d

Susceptibility Indices followed by the same letter (a to d) are not significantly different from each other at P = 0.05. Duncan's Multiple Range Test.

Significant differences were found in the Susceptibility Indices, indicating that some of the varieties studied were more susceptible to infestation by *S. zeamais* than other varieties. Among the varieties, Kawanzie was the least susceptible and Pool 16 SR the most susceptible. Grains of Pool 16 EV 85, Gandajika 8149 and Dobidi did not differ significantly (1t P = 0.05) from Kawanzie. However, the three local varieties, namely H o Local Two, H o Local One, and Pokoase Local were more susceptible to infestation than Kawanzie. Significant differences in susceptibilities were not observed (at P = 0.05) between Pool 16 SR, the Three Local varieties, Composite 4, Aburotia CRI, and Dobidi.

Effect of S. zeamais on Viability

As the number of adult emergence holes observed on each maize grain increased, the viability of the seed decreased (Table 2). However, it was not possible to determine the correlation between emergence holes and vigour of the growing maize seedlings.

Table 2. Effect of *S. zeamais* Infestation on Viability of Maize Seeds

No. of emergence holes per seed	No. of test seeds of each variety	Mean percentage germination after 7 days for all 10 varieties
0	60	88 a
1	40	64 b
2	20	42 c
3	10	0 d

Effect of Proximate Analyses on Susceptibility

Results of the proximate analyses of the ten varieties are shown in Table 3.

Table 3. Proximate Analysis of 10 Maize Varieties Used in Susceptibility Tests

Maize variety	% Ash	% Fat	% Protein	Carbohydrate	K(mg/ 100g)	Fe(mg/ 100g)	Ca(mg/ 100g)
Kawanzie	1.3	3.9	9.5	72.29	622.6	5.4	39.0
Pool 16 EV85	1.4	3.5	10.6	71.47	285.8	4.5	42.0
Gandajika	1.4	3.6	10.5	71.47	329.3	4.8	45.0
Dobidi	1.4	4.6	10.3	70.65	304.1	3.0	29.5
Alburotia CRI	1.3	1.8	10.9	72.96	187.0	5.1	97.0
H o Local Two	1.5	6.2	8.4	70.88	373.4	3.7	32.0
H o Local One	1.2	4.4	9.8	71.59	219.5	5.2	68.0
Composite 4	1.3	2.9	9.5	74.30	622.6	5.4	39.0
Pokoase Local	1.7	2.9	11.9	70.48	366.7	3.6	68.0
Pool 16 SR	1.2	3.3	9.9	73.56	295.1	3.5	40.0

A simple linear correlation analysis was conducted to determine the degree of association between the proximate analyses and Susceptibility Indices. The coefficient of correlation (r) was calculated as +0.42, -0.07, -0.08, +0.025, -0.07, +0.32, and -0.04 for ash, fat, protein, carbohydrate, phosphorus, calcium, and iron contents, respectively. No significant positive or negative correlation at P = 0.05 could be established for the proximate analyses and Susceptibility Index as tabular r values for (10-2) degrees of freedom was 0.632.

Discussion

The experiment was carried out on a "no-choice" condition for the insect. This condition bears little resemblance to field and store conditions, where an insect chooses the susceptible variety. The Susceptibility Indices are therefore a reflection of the inherent susceptibilities of the grains. These include hardness of the endosperm (Singh and McCain, 1963; Dobie, 1974), thickness and toughness of grain seed coat (Schoonhoven, 1972 and Dobie, 1974 cited in Schulten, 1976), nutritional factors such as sugar content (Singh and McCain, 1963) amylose content (Gupta et al., 1970). It is possible that for these varieties, ash, fat, protein, carbohydrate, phosphorus, iron, and calcium contents of the grains are not important factors in their susceptibility. Even though endosperm hardness and grain seed coat (pericarp) were not analyzed in the present study, they may be important factors contributing to susceptibilities. Further work is needed in this area.

In Ghana, newly harvested maize is less preferable to old stocks for traditional food preparation such as "kenkey", "banku", and "akple". The old stocks may be more infested leading to reduced viabilities, and poor quality and quantity. It is therefore necessary to protect maize from insect attack in order to maintain good seed stocks. A non-chemical method of protection should be preferred to conventional dependence on insecticides.

Conclusion

With the exception of Composite 4 and Pool 16 SR, the grains of the newly introduced varieties are less susceptible to infestation in storage by *S. zeamais* than the local varieties. Therefore, the new varieties will suffer less damage if the levels of the field infestation of both types are the same. In practice, this does not happen in the field, due to the poor husk cover of the new varieties. There is a further need to study how the field infestation affects storability of the grains of the different varieties. This could then give a true indication of which variety really stores better or is less susceptible to *S. zeamais* attack. The potential yield of a new variety is very important when deciding whether to grow it. Therefore, "the increase in losses due to changing to a new variety must exceed the expected increase in yield before the insect susceptibility factor should prevent the new variety from being grown" (Falomo, 1978). More work on breeding is necessary to develop highly resistant insect varieties with good nutritional and processing characteristics.

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DISCUSSION

SCHEURING: How do you explain the differences regarding susceptibility? Has it to do with grain components or the shell of the grain?

VOWOTOR: The improved varieties had harder grains. We determined different grain components and found out that was not the reason.

ARODOKOUN: Cette étude devrait permettre de faire des recommendations pour l'amélioration variétale. Pourquoi il n'y a pas eu l'analyse de la texture des grains à l'instar de l'analyse chimique? Et puis, quelle recommendation on peut déjà faire à partir de ces résultats?

VOWOTOR: Je n'ai pas pu vous parler des recommendations à cause du manque de temps. Il faut qu'en plus des caractéristiques d'ordre agronomique (haut rendement, etc.) les sélectionneurs et les améliorateurs tiennent compte également des aspects d'aptitude au stockage, à la mouture et des caractéristiques organoleptiques.