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Screening for sources of resistance to the maize weevil on stored maize varieties obtained in the Gambia

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ABSTRACT
The maize weevil, *Sitophilus zeamais*, is a serious stored product pest of maize in the tropical and sub-tropical countries. This study evaluated commonly used maize varieties collected from the National Agricultural Research Institute against the maize weevil. Using the Dobie index of susceptibility, eleven maize varieties were screened for resistance to the maize weevil. The Varieties of TZEE-Y and JEKA were resistant to *S. zeamais,* while TZE-W was susceptible, and the mechanism of resistance was antibiosis. The resistant varieties had a relatively longer median development time (MDT) and fewer F_1 progeny emergence. Protein (r = -0.60*) content correlated negatively and significantly with susceptibility index. The susceptibility index showed a negative and significant relationship to MDT (R^2 = 0.89*) and a positive relationship to F1 progeny (R^2 = 0.90*). An increase in F1 progeny indicates an increase in grain damage (R^2 = 0.95) and weight loss (R^2 = 0.72). The maize varieties TZEE-Y and JEKA were the most resistant to the maize weevil, making them promising for control.

Keywords: Antibiosis, maize growers, resistance, *Sitophilus zeamais*, varieties

1. Introduction

In developing countries, post-harvest losses due to storage pests often result in shortages in the consumption demand of maize (Udo, 2005). Maize grains in storage can be infested and destroyed by numerous insect pests, especially when the grains are stored on-farm without insecticide treatment or the right moisture content (Midega *et al*., 2016). The maize weevil, *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae), is among the most destructive insect pests of stored cereals in tropical and sub-tropical regions (Throne, 1994). It bores holes and consumes a large portion of the grain's endosperm, which destroys the germ and consequently diminishes the nutritive value and viability of the grain.

Resistance in stored maize to *S. zeamais* attack has been attributed to a number of factors. Bergvinson (2001) reported that there were strong correlations between insect resistance, kernel hardness and elevated levels of diphenolic acids located within the pericarp of the kernel. Similarly, maize weevil resistance in maize genotypes was found to be associated with elevated levels of cell-wall cross-linking components such as phenolic acids, diferulates and structural proteins (Garcia-Lara *et al.,* 2004)

Presently, conventional insecticides are widely used for the control of stored insect pests and have usually provided an effective defense (Chikukura *et al*., 2011). However, their availability in distant rural areas of the country is unreliable; also, they are often diluted to ineffective concentrations and they are toxic to humans and contaminate the environment (Stevenson *et al.,* 2012). These constraints associated with the use of conventional insecticides have led to an increased interest in research into the use of resistant varieties for protection against insect pests in storage (Sola *et al*., 2014).

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2. Materials and Methods

2.1. Culturing of study insects

Sitophilus zeamais were obtained from infested maize samples collected from Brikama, Barra and Basse, the Gambia, and cultured on maize (Swan-2) seeds. Fifty adult *S. zeamais* of mixed sexes and ages were cultured on clean and disinfested maize seeds in 500 ml capacity plastic jars on 250 g of seeds. For ventilation and to prevent weevil escape, the jars were covered with muslin cloth and secured with rubber bands before being placed in the laboratory at ambient temperature (25±2 °C) and relative humidity (70 ± 5%). The weevils were allowed to oviposit for seven days, thereafter; all adults were removed and placed in another set of jars, the newly emerged adult *Sitophilus zeamais* were used for the study (Adedire and Lajide, 1999).

2.2. Source of maize varieties

A total of 11 maize varieties sourced from the National Agricultural Research Institute (NARI), The Gambia, were used in this trial. Freshly harvested seeds of each variety (DMR-SR, Swan-2, DMR-ESR-W, DMR-ESR-Y, TZEF-Y, TZEE-Y, TZE-Y, TZE-W, NCB, JEKA and MASARABODE) were cleaned and disinfested by keeping them in a deep freezer at -20±2 °C for two weeks after which the varieties were kept in 500 ml plastic jars in the laboratory.

2.3. Evaluation of maize varieties for resistance against *Sitophilus zeamais*

A sample of 100 g of each variety of maize was placed in a 500 ml plastic jar covered with a muslin cloth for ventilation and to prevent weevil escape. Five pairs of *Sitophilus zeamais* adults (7-10 days old) were introduced to the jars of each variety and kept for seven days for oviposition, after which the adults were removed (Derera *et al.*, 2001). Seeds of each variety without *S. zeamais* kept under similar conditions served as control.

The treatments were arranged in a Randomised Complete Block Design with four replicates in the laboratory shelves at NARI, Brikama, the Gambia. Data collected on the parental insects alive and dead, weight loss, median development time (MDT), F_1 progeny was related to each variety.

2.4. Median developmental time

This was the duration from the middle of the oviposition period to when fifty percent of the F_1 adults emerged. The counting was started from the 4th day after the introduction of the adults and after all F_1 adults had emerged. The fifty percent point for each variety was determined and the MDT was calculated.

2.5. F_1 adult emergence

The number of insects that emerged from each variety was counted every two days, starting from the appearance of the first F_1 emergence until 56 days post adult introduction (Nwana and Akibi-Betts, 1982). The Experiment ended when no adult emergence was recorded for four consecutive days.

2.6. Percentage weight loss

Percentage weight loss was determined after 56 days by counting and recording the total number of damaged and undamaged and taking the weight of the damaged and undamaged seeds.

$$\%\ \text{Weight loss} = \frac{(\text{Wu}\times \text{Nd})-(\text{Wd}\times \text{Nu})}{\text{Wu}(\text{Nd}+\text{Nu})} \times 100 \quad \text{.......} (1)$$

Where Wu = weight of undamaged; Nd = number of damaged; Wd = weight of damaged Nu = number of undamaged (Dobie, 1991)

2.7. Index of susceptibility

This was determined by the number of F_1 progeny and the length of median developmental time (the period from half the oviposition period to when 50% of the F_1 progeny had emerged).
I- Index of susceptibility = 100 × [log$_e$ (total number of F_1 progeny emerged) / (median development time)] .... (2)

II- Maize varieties were grouped using a susceptibility index range of 0-11, where; 0 - 3 = resistant, 4 - 7 = moderately resistant, 8 - 10 = susceptible and ≥ 11 = highly susceptible (Dobie, 1974).

2.8. Statistical analysis

Data collected on insect counts were subjected to square root transformation (√x+1) and analysis of variance (ANOVA) using the SAS (JMP 14) method. Means were separated with Student's Newman-Keuls tests at 5% probability. Data on susceptibility index were calculated using (Log_eF_1/MDT *100), were F_1= total progeny emergence and MDT= median development time. Correlation analysis was also carried out to determine the relationships between different proximate constituents of maize varieties.

3. Results

Significant differences (p<0.05) were observed among maize varieties for the number of F_1 progeny emergence. The highest number of F_1 progeny was recorded on TZE-W, DMR-ESR-W, SWAN-2, TZEF-Y and DMR-SR with 42.50±5.66, 33.00±5.66, 29.75±5.66, and 29.50±5.66, respectively, while the lowest was registered in TZEE-Y (3.75±5.66) and JEKA (4.50±5.66) (Table 1).

Median development time was significantly different (p<0.05) among the varieties. The median development time (MDT) ranged from 35±1.41 days for DMR-SR to 45±1.41 days for JEKA. *S. zeamais* fed on the varieties DMR-SR, TZE-W, DMR-ESR-W, NCB, SWAN-2, TZEF-Y and DMR-ESR-Y had relatively short MDTs of 35.00±1.41, 36.50±1.41, 36.75±1.41, 36.75±1.41, 37.50±1.41, 37.75±1.41, respectively, while JEKA (45.00±1.41), TZEE-Y (42.25±1.41), TZE-Y (39.25±1.41) and MASARABODE (39.25±1.41) had the longest MDT (Table 1). The resistant varieties had a relatively longer median development time to the moderately resistant and susceptible varieties. Susceptible varieties allow weevils to exhibit reduced periods of developmental cycles, thereby increasing insect population and crop damage. In the other hand, prolonged development periods may result in the reduction of number of generations in a season.

Table 1: Some biological and damage characteristics of *Sitophilus zeamais* fed to the eleven maize varieties in The Gambia

Variety	Median dev. time (days ± S.E)	Total f₁ progeny	Grain weight loss (%)	Grain damage (%)
Jeka	45.00±1.41a	4.50±5.66c	0.24b	2.50ab
TZEE-Y	42.25±1.41ab	3.75±5.66c	0.24b	2.00b
Masarabode	39.25±1.41bc	13.50±5.66bc	0.45b	4.50ab
TZE-Y	39.25±1.41bc	17.75±5.66abc	0.49b	4.25ab
TZEF-Y	37.75±1.41bc	29.50±5.66abc	0.69ab	6.00ab
DMR-ESR-Y	37.50±1.41bc	24.25±5.66abc	0.67ab	4.75ab
Swan-2	37.50±1.41bc	29.75±5.66abc	1.20a	6.25ab
DMR-ESR-W	36.75±1.41bc	33.00±5.66ab	1.19a	6.25ab
NCB	36.75±1.41bc	26.50±5.66abc	0.74ab	5.50ab
TZE-W	36.50±1.41bc	42.50±5.66a	0.93ab	8.25a
DMR-SR	35.00±1.41c	29.00±5.66abc	0.68ab	5.50ab

Means followed by same letter in a column are not significantly different (p>0.05) using Student Newman Keuls test.

3.1. Susceptibility index of maize varieties

The index of susceptibility was significantly different (p>0.05) among the varieties, ranging from 2.95 in TZEE-Y to 10.00 in TZE-W. The varieties TZEE-Y and JEKA with susceptibility index 2.95 and 3.32 were rated as resistant, whereas MASARABODE (6.56) and TZE-Y (7.38) were moderately resistant, and TZE-W, DMR-SR, DMR-ESR-W, SWAN-2, NCB, TZEF-Y, DMR-ESR-Y varieties with susceptibility index 10.00, 9.60, 9.52, 8.96, 8.66, 8.55 and 8.33, respectively, were rated susceptible (Fig. 1). The variation in susceptibility index among maize varieties is responsible for the inherent ability of a variety to resist *S. zeamais* development activities. Among the eleven maize varieties tested against *S. zeamais,* two varieties, JEKA and TZEE-Y, were resistant, two varieties, MASARABODE and TZE-Y, were moderately resistant, whilst the other seven varieties were susceptible. According to

Hober (1988), the index of susceptibility is based on the assumption that the more F_1 progeny and shorter duration of development, the less resistant the seeds would be.

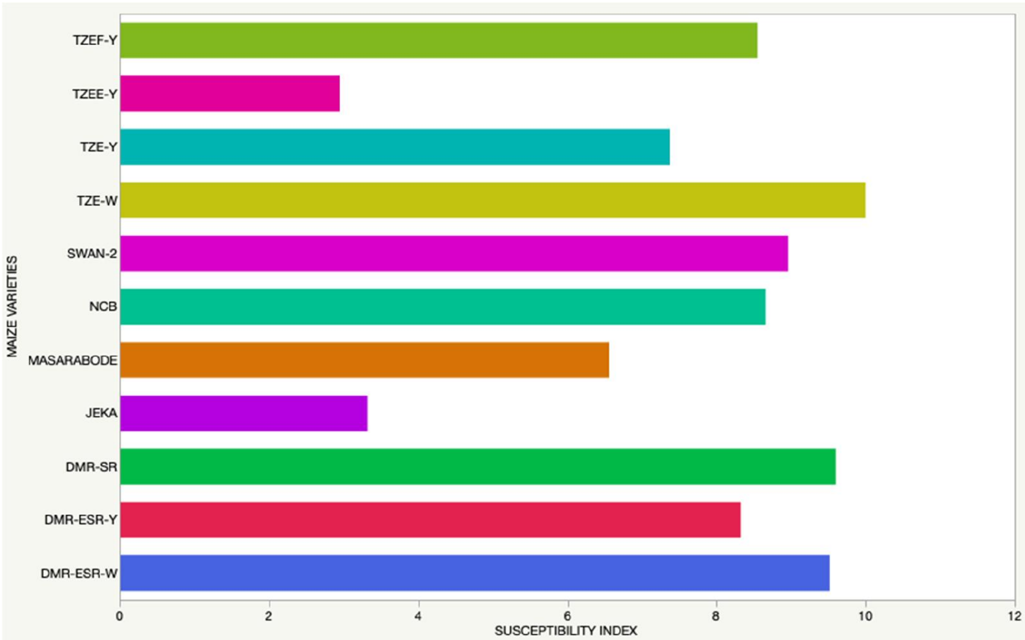

Fig. 1: Susceptibility indices of the eleven maize varieties tested for resistance against *Sitophilus zea mais* (0 to 11 scale), where; 0-3 = resistant, 4 – 7 = moderately resistant, 8 – 10 = susceptible and >1 1 = highly susceptible

3.2. Grain damage and weight loss

Grain damage was significantly different (p<0.05) among the varieties (Table 1). The highest grain damage values were recorded in TZE-W, DMR-ESR-W and SWAN-2 at 8.25, 6.25 and 6.25%, respectively, while the least grain damage was recorded in TZEE-Y, JEKA, TZE-Y and MASARABODE with 2.00, 2.50, 4.25 and 4.50, respectively (Table 1). Significant differences (p<0.05) were observed in percent weight loss. The highest weight loss was observed in SWAN-2 and DMR-ESR-W, while JEKA and TZEE-Y recorded the least weight loss among the varieties (Table 1). There were no highly susceptible varieties. Susceptibility index showed a negative relationship to MDT (R^2 = 0.89) and a positive relationship to F1 progeny (R^2 = 0.90) (Figure 2). Increase in F1 progeny indicates an increase in grain damage (R^2 = 0.95) and weight loss (R^2 = 0.72) (Figure 3). Abraham (1991) mentioned that the level of damage in storage is dependent on the population of emerging adults during each generation and the duration of each life cycle. Fewer eggs laid, lower adult bruchid population emergence and thus less damaged with no weight loss was observed on resistant cowpea accessions fed to the bruchid beetle (Azeez and Pitan, 2014). TZEF-Y with high protein content was found to be susceptible, Babarinde *et al.* (2008) reported that *S. zeamais* caused significant damage on carbohydrate-rich cereals and tubers, therefore its (TZEF-Y) susceptibility could be associated with the high percentage of carbohydrates content.

(a) (b)

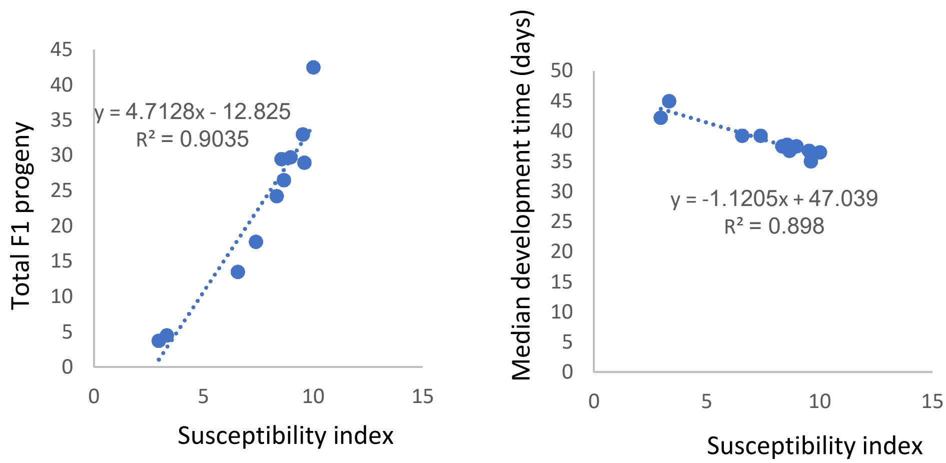

Figure 2: Correlation between (a) F1 progeny (b) median development time and susceptibility index.

(a) (b)

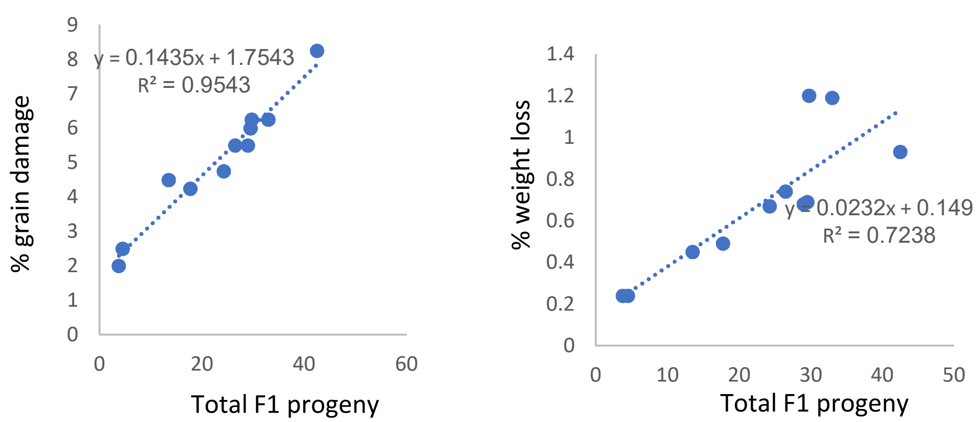

Fig. 3: Correlation between (a) % grain damage (b) % weight loss and F1 progeny

3.3. Determination of the basis of resistance in eleven maize varieties

Maize varieties were significantly different ($p<0.05$) in primary metabolite contents (Table 2). Protein content was significantly highest ($p<0.05$) in the resistant varieties (TZEE-Y and JEKA) with 13.88 and 13.84%, respectively, and the least protein content was recorded in susceptible varieties (DMR-SR, DMR-ESR-Y and TZE-W) at 13.22, 13.43 and 13.43%, respectively. The resistant varieties were found to contain the highest levels of dry matter, crude fiber, fat, and ash content but were low in moisture content (Table 2). Carbohydrate content varied significantly ($p<0.05$) among maize varieties with TZEF-Y recording the highest content of 66.16%. Moisture content was lowest in TZEE-Y, JEKA and TZEF-Y, while TZE-W and TZE-Y contain the highest moisture of 12.85 and 12.75%, respectively (Table 2). Protein content ($r = –60$), Crude fiber ($r = –60$), and Crude fat ($r = –61$) showed significant correlation and were all negatively correlated to the susceptibility index (Table 3). Dobie (1974) and Tepping *et al.* (1988) attributed resistance to insect attack on maize varieties to physio-chemical factors such as grain hardness, pericarp surface texture, lipid and protein content, while it was attributed to phenolic compounds content by Serratos *et al.* (1987). TZEF-Y with high protein content was found to be susceptible, Babarinde *et al.* (2008) reported that *S. zeamais* caused significant damage on carbohydrate-rich cereals and tubers, therefore its (TZEF-Y) susceptibility could be associated with the high percentage of carbohydrates content.

Table 2: Proximate constituents of the eleven maize varieties tested for resistance to *Sitophilus zeamais*.

Variety	Moisture (%)	Dry matter (%)	Fat (%)	Ash (%)	Crude fibre (%)	Crude protein (%)	Carbohydrates (%)
TZE-W	12.85a	87.15d	3.42c	1.18b	3.21c	13.43e	65.91bc
TZE-Y	12.75ab	87.25d	3.48bc	1.21b	3.22c	13.51d	65.85bcd
Swan-2	12.43abc	87.57c	3.49bc	1.28a	3.25bc	13.61c	65.94b
NCB	12.39abc	87.61c	3.51abc	1.32a	3.24c	13.64c	65.90bcd
Masarabode	12.29abc	87.71bc	3.54abc	1.32a	3.28abc	13.70b	65.87bcd
DMR-ESR-W	12.26abc	87.74bc	3.58abc	1.32a	3.28abc	13.73b	65.83bcd
DMR-SR	12.26abc	87.74bc	3.56abc	1.34a	3.30abc	13.22f	65.82bcd
DMR-ESR-Y	12.17bc	87.83b	3.61ab	1.35a	3.34ab	13.43b	65.77d
Jeka	11.96c	88.04a	3.63ab	1.35a	3.36a	13.84a	65.86bcd
TZEF-Y	11.95c	88.05a	3.63ab	1.37a	3.36a	13.86a	66.16a
TZEE-Y	11.87c	88.11a	3.68a	1.38a	3.38a	13.88a	65.79cd

Means followed by same letter in eleven are not significantly different ($p<0.05$) using Student Neuman Keuls test.

Table 3: Correlation coefficients of the association between primary metabolite constituents obtained in eleven maize varieties and damage by *Sitophilus zeamais*

Parameter	Crude protein	Moisture	Dry matter	Crude fat	Ash content	Crude fibre	Carbohydrate
S. I	-0.60*	0.57	-0.57	-0.61*	-0.43	-0.60*	0.26
M. D. T	0.62*	-0.48	0.47	0.50	0.28	0.52	-0.15
F_1 progeny	-0.51	0.56	-0.56	-0.60*	-0.47	-0.57	-0.33
WL	-0.31	0.43	-0.43	-0.50	-0.35	-0.52	0.22
GD	-0.50	0.62*	-0.61*	-0.69*	-0.54	-0.64*	0.40

S. I= Susceptibility index, M. D. T= Median development time, F_1= First filial generation, W. L= Weight loss, G. D= Grain damage

4. Conclusion

The study shows Jeka and TZEE-Y as the most tolerant varieties to the maize weevil with limited weight loss, grain damage, F_1 progeny emergence and median development time, making them suitable choices for maize growers in order to safe considerable quantity and quality of grains for family consumption and income earnings.

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Reference

Abraham, T., 1991. The biology, significance and control of the maize weevil, *Sitophilus zeamais*Motsch. (Coleoptera: Curculionidae) on stored maize, MSc. Thesis, Alemaya University of Agriculture, Alemaya, Ethiopia.

Adedire, C.O. and L. Lajide, 1999. Efficacy of powders of some tropical plants in the control of the pulse beetle, *Callosobruchus maculatus* (F.) (Coleoptera: Bostrichidae). Applied Tropical Agriculture 6:11-15.

Azeez, O.M., O.O.R. Pitan, 2014. Comparative seed resistance in eighty cowpea accessions to the seed bruchid, *Callosobruchus maculatus* (Fabricius) (Coleoptera: Bruchidae), Archives of Phytopathology and Plant Protection, 47:15, 1806-1814.

Babarinde, S.A., A. Sosina, and E.I. Oyeyiola, 2008. Susceptibility of the selected crops in storage to *Sitophilus zeamais* (Motschulsky) in Southwestern Nigeria. Journal of Plant Protection Research 48(4): 543-550.

Bergvinson, D. J., 2001. Storage Pest Resistance in Maize. In Maize programme. Maize Research Highlights. 1999-2000. CIMMYT, Mexico D. F., 32-39. Mexico.

Chikukura, L., B. Mvumi, R. Chikonzo, and C. Chenzara, 2011. Evaluation of Selected Indigenous Pesticidal Plant Powders against Stored Maize and Cowpeas Insect Pests. African Crop Science Conference Proceedings 10, 189-192.

Derera, J., K.V. Pixley, and P.D. Giga, 2001. Resistance of maize to the maize weevil: I-Antibiosis. African Crop Science Journal 9: 43-440.

Dobie, P. 1974. The laboratory assessment of the inherent susceptibility of maize varieties to post-harvest infestation by *Sitophilus zeamais* (Motschulsky) (Coleoptera: Curculionidae). Journal of Stored Products Research 10: 179-183. Elsevier Science Ltd., England.

Dobie, P., C.P. Haines, R.J. Hodges, P.F. Prevett, and D.P. Rees, 1991. Insects and Arachnids of tropical stored products: Their biology and identification (training manual). (Natural Resources Institute, Chatham Maritime, UK,) P. 232.

García-Lara, S., D.J. Bergvinson, A.J. Burt, A.I. Ramputh, D.M. Díaz-Pontones, and J.T. Arnason, 2004. The role of pericarp cell wall components in maize weevil resistance. Crop Science 44: 1546-1552.

Hober, E. 1988. Methods to detect and evaluate resistance in maize to seed insects in the field and in storage. Proceedings of the International Symposium on Methodologies on Developing Host Plant Resistance to Maize Insects, March 9-14, 1987, CIMMYT, Mexico, pp.140-150.

Midega, C. A. O., A.W. Murage, J.O. Pittchar, and Z.R. Khan, 2016. Managing storage pests of maize: Farmers' knowledge, perceptions and practices in western Kenya. Crop Protection 90: 142-149.

Nwana, I. E. and D.T. Akibo-Betts, 1982. The resistance of some rice varieties to damage by *Sitophilus zeamais* Motsch., during storage. Tropical Stored Product Information, 43: 10-15.

Serratos, A., J.T. Amason, C. Nozzolillo, J.D.H. Lambert, B.J.R. Philogene, K. Davidson, L. Peacock, J. Atkinson, and P. Morand, 1987. Contribution of phenolic antifeedants to resistance of maize populations to the maize weevil, *Sitophilus zeamais*. Journal of chemical Ecology 13: 751.

Stevenson, P. C., G.C. Kite, G.P. Lewis, F. Forest, S.P. Nyirenda, S.R. Belmain, G.W. Sileshi, and N.C. Veitch, 2012. Distinct Chemotypes of *Tephrosiavogelii*and Implications for Their Use in Pest Control and Soil Enrichment. Phytochemistry, 78: 135-146.

Sola, P., B. Mvumi, J. Ogendo, O. Mponda, J. Kamanula, S. Nyirenda, S. Belmain, and P. Stevenson, 2014. Botanical Pesticide Production, Trade and Regulatory Mechanisms in Sub-Saharan Africa: Making a Case for Plant-Based Pesticidal Products. Food Security 6: 369-384. http://dx.doi.org/10.1007/s12571-014-0343-7

Tepping, P. W., D.E. Legg, J.G. Rodriguez, and C.G. Ponelei, 1988. Influence of maize pericarp surface relief on resistance to the maize weevil (Coleoptera: Curculionidae). Journal of Kansas Entomological Society, 61: 237-241.

Throne, J. E. 1994. Life history of immature *S. zeamais* (Coleoptera: Curculionidae) on corn stored at constant temperatures and relative humidity in the laboratory. Environmental Entomology 23: 1459-1471.

Udo, I. O. 2005. Evaluation of the potential of some local spices as stored grain protectants against the maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae). Journal of Applied Sciences and Environmental Management 9(1): 165–168.