Management of the Maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) using Botanical Insecticides on three Maize Genotypes

Girma Demissie[1], Tadele Tefera[2] and Abraham Tadesse[3]
[1]Bako National Maize Research Project, P.O.Box 03, West Shoa, Ethiopia, [2]Georg-August-University, Department of Crop Science, Agricultural Entomology Section, Grisebachstr. 6, 37077 Goettingen, Germany, [3] Ethiopian Institute of Agricultural Research, P.O.Box 2003, Addis Ababa, Ethiopia.

Abstract

The maize weevil, Sitophilus zeamais, is a major insect pest of stored maize in Ethiopia. The effectiveness of three botanicals viz., Neem (Azadirachta indica A. Juss) seed powder (NSP), Mexican tea (Chenopodium ambrosioides L.) powder (MTP) and triplex at three different rates were studied for the management of the maize weevil on three maize genotype (SZSYNA99- F_2 -33-4-2 X SC_{22}, SZSYNA99-F_2 -79-4-3 x CML-197 and a commercial variety BH-140. The botanical treatments except NSP caused high mortality (95 – 100%) 7-days after exposure, and reduced progeny emergence and grain damage. However, NSP inflicted significant higher mortality than the untreated check 21 days after infestation. At the highest dosage NSP caused similar mortality with the standard insecticide, Pirimiphos-methyl 2 % dust, 28 days after infestation. Maize genotypes did not show significant response to the pest. Seed germination was not affected by any of the treatments. It is, therefore, recommended that MTP, NSP and triplex can be considered as a potential component in an effort to establish integrated management strategy against the maize weevil on maize.

Introduction

Food security and human nutritional status of the target clients are directly impacted by losses in quantity and quality of the harvested crop. In some cases, post-harvest losses due to pests outweigh any reasonable hope for increases in productivity through improved germplasm and pre-harvest management. The maize weevil, *Sitophilus zeamais* Motsch., is one of the most serious cosmopolitan field-to-store pest that ranked as the principal post-harvest pest of maize in the tropics (Bosque-Perez and Buddenhagen, 1992) and in Ethiopia (Abraham, 1991). It causes substantial quantitative and qualitative losses manifested by seed perforation, and reductions in weight, market value and seed germination. Losses ranging from 20 to 30% are common in some localities in Ethiopia (Abraham, 1991; Emana, 1999). Under farm-storage conditions in the Bako area, up to 100% damage to maize stored for 6-8 months have been reported (Abraham, 1991).

Storing grain is not only an activity to reserve food but also it can be considered as an investment of time and material from which a profit is expected. In Ethiopia, maize sold six months after harvest, when grain is relatively scarce, generally commands a much higher price than maize sold at the time of harvest, when maize and other foods are plentiful (Beyene et al., 1997). But producers are frequently forced to sell grain earlier than they would wish mainly because of the fear of storage pests (Abraham, 1991).

Use of synthetic insecticides provides effective protection of stored grains from storage insect pests. However, subsistence farmers cannot afford the use of insecticide chemicals. Therefore, alternative options suitable to the conditions of poor farmers should be available. Some of these options include use of pest resistant crop varieties and botanical insecticides. The use of locally available botanicals to limit insect development and damage in stored food stuffs are common practices in developing countries (Golob and Webley, 1980; Firdisa and Abraham, 1999). Some studies made in Ethiopia indicated that there are variations among maize genotypes for resistance to the maize weevil (Abraham, 1991). The integration of varietals resistance with other non-chemical natural products for the maize weevil control is likely to be more successful than a sole dependence on either of them. This paper reports results of studies on the effectiveness of three botanicals, namely neem seed powder (NSP), Mexican tea powder (MTP) and triplex, on the maize weevil on three maize genotypes with different resistance reactions to the pest.

Materials and Methods

Insect rearing

Culture of parent adult weevils was collected from the Bako Agricultural Research Center (BARC) maize seed store in July 2005; and reared in the same laboratory where the experiment was conducted. The weevils were cultured on BH-540 maize hybrid which is commonly grown by farmers in the Bako area. The seeds were disinfested by keeping in a deep freezer at -20 ± 2°c for two weeks. After disinfestations, seeds were cleaned and kept for two weeks at the experimental conditions for acclimatization and adjusted to moisture contents of 12 to 13% before use. Two kilograms of the disinfested seeds were placed in four-liter capacity plastic containers covered with perforated lids. About 800 unsexed adult maize weevils were introduced onto the grain in each plastic container and allowed to oviposit for two weeks, after which they were removed and discarded. The grain was kept for progeny emergence. According to Abraham (1991), the average developmental time of the maize weevil on maize in the laboratory conditions at Bako was about 42 days. Based on this information, progeny emergence was monitored daily and those emerged on the same day were transferred to fresh seed in plastic containers with lids and kept under the experimental conditions until a sufficient number of weevils were obtained for the experiment.

Maize genotypes

Seeds of three freshly harvested maize genotypes (Table 1) were cleaned, disinfested and equilibrated to the experimental conditions (25 ± 5°C and 70 ± 5% r. h.). The moisture content of the seeds was adjusted to 12-13% (Adams and Schulten 1978). About 0.2 kg of seeds were then selected from each of the three maize genotypes and put in a 250 cm^3 glass jar with brass screen lids allowing ventilation.

Table 1. Pedigree, seed surface texture and color of the maize genotypes used for the experiment

Code	Pedigree	Grain texture	Grain color
G1	SZSYNA99- F_2-33-4-2 X SC_{22}	Dent-flint	White
G2	SZSYNA99-F_2-79-4-3 X CML-197	Flint	White
G3	BH-140 (Commercial variety)	Dent	White

Botanical treatments

The botanicals used include NSP, MTP and triplex (*Endod* - a by-product of the Midroc soap factory). Leaves of Mexican tea were collected from along the roadside in Addis Ababa and Holleta. Neem seed was collected from Dire Dawa. The plant materials were allowed to dry under shade for about one week. The dried leaves and seeds were ground separately in to powder using mortar and pestle. Triplex was obtained through the Ethiopian Science and Technology Commission, Addis Ababa. The botanicals and their respective proportions (w/w) used were as follows; NSP at 0.5, 1, 2%, MTP at 1.2, 2, 5% and triplex at 0.4, 0.2, 1.25%.

Treatment application

Three different rates of each botanical were weighed and added to the grain contained in each glass jar and shaken well for uniform coating. Fifty freshly emerged adult weevils were introduced into each jar and covered with a ventilated lid. Two treatments, the standard insecticide Pirimiphos-methyl 2% dust and an untreated check, were included for comparison. The experiment was laid out in a randomized complete block design with a 3 x 3 x 3 factorial arrangements consisting of the three maize genotypes, three botanicals and three rates of application. The treatments were replicated three times. The temperature and relative humidity conditions of the laboratory were recorded daily until the end of the experiment. The mean daily temperature and r. h. ranged from 20 to 30 ^{0}C and 66.5 to 76.5%, respectively.

Data collected

Mortality: Mortality was assessed 3, 7, 15, 21 and 28 days after treatment application. The assessment periods selected were based on an earlier report by Dobie (1974). Dead adult weevils were removed and counted during each assessment.

F_1 progeny emergence: After removing dead and alive weevils, the seeds were kept under the same conditions for the F_1 progenies to emerge. The number of F_1 progeny weevils emerging was recorded every second day for 60 days. Emerging adults were removed from the jar after each assessment. This continued until progeny weevil emergence ceased.

Grain damage and weight loss: Ninety days after the introduction of adult maize weevils, the number and weight of damaged and undamaged grains were recorded. Grain weight loss was calculated by using the count and weigh method (Adams and Schulten, 1978).

$$\text{Grain weight Loss (\%)} = \frac{(Wu * Nd) - (Wd * Nu) * 100}{Wu * (Nd + Nu)}$$

Where: Wu = weight of undamaged grains, Nd = number of damaged grains, Wd = weight of damaged grains and Nu = number of undamaged grains

Seed germination: Seed germination was tested using 30 randomly picked seeds from undamaged grains after separation of damaged and undamaged grains in each jar. The seeds were placed on a moistened filter paper in plastic Petri dishes and the number of germinated seeds was recorded after ten days.

Statistical analysis

The number of dead weevils in each replicate was converted into proportions of the total number of adult weevils introduced and expressed as percentage. Mortality data were corrected for control mortality using Abbott's correction formula,

$$\% CM = \frac{(\% T - \% C)}{(100 - \% C)} * 100$$

where CM is corrected mortality, T is mortality in treated grains and C is mortality in untreated grains (Abbott, 1925). Control mortality did not exceed 10%. Damaged seeds were expressed as a percentage of the total number of grains in each replicate. Weight loss data were also expressed as percentages. Percentage mortality and damaged grain data were angular transformed, while percentage seed germination and the number of progeny were square root transformed, prior to statistical analysis, in order to stabilize the variances. All data were subjected to factorial analysis consisting of three main effects: botanicals, their rates and genotypes. Significant differences between means were determined using Student-Newman-Keuls Test. The analyses were performed using SPSS version 12.5 computer software. Since there were no significant differences in adult weevil mortality between the main effects of genotypes and rates and the interaction between genotype and botanicals, genotype and rate, and among genotype, botanicals and rate the results were not shown.

Results

Adult weevil mortality

There were significant differences in adult weevil mortality between the botanicals, and the interactions between botanicals and their rates. Mexican tea powder (MTP) caused the highest adult weevils mortality (100%) followed by triplex (90.3%) while NSP caused the lowest mortality (12.4%), three days after treatment (Table 2). All rates of MTP and triplex were equally effective against the maize weevil.

Table 2. Main effects of three botanicals and their different rates on the mortality of adult maize weevil different dates days after exposure to the three maize genotypes.

Days after exposure	Main effect	Neem seed powder rate			Mexican tea powder rate			Triplex rate		
		0.5	1	2	1.25	2.5	5	0.1	0.2	0.4
Three	Rate	4.4±2.9b	11.3±3.3c	21.6±4.7c	100a	100a	100a	85.4±5.5b	92.2±2.31b	93.3±1.1b
	Botanicals		12.4±2.7c			100a			90.3±1.63b	
Seven	Rate	9.8± 77.43d	40.2 11.5c	68.7±6.4b	-*	-	-	96.21±0.78a	99.13±0.45a	99.77±1.26a
	Botanicals		39.6 ± 6.38b			-			98.4 ± 0.79a	
Fifteen	Rate	18.4±4.3d	56.8±8.4c	85.1±10.8b	-	-	-	100a	100a	100a
	Botanicals		53.4± 6.37b			-			100a	
Twenty one	Rate	25.8±9.2d	64.7±9.2c	91.3±6.3b	-	-	-	-	-	-
	Botanicals		60.6±6.04			-			-	
Twenty eight	Rate	33.6±3.5d	69.8±7.5c	94.8±4.2b	-	-	-	-	-	-
	Botanicals		66.07±5.78			-			-	

Means followed by the same letter in a row are not significantly different from each other at $p < 0.05$

* = Data not available as all treated insects died.

Seven days after exposure, efficacy of NSP and triplex increased in a similar pattern to day 3 (Table 2). Triplex caused 98.4% mortality whereas NSP caused a mortality of 39.6%. Triplex inflicted 100% mortality following 15 days after treatment. After 21 and 28 days of exposure, weevil mortality due to NSP increased significantly, and its highest rate (2%) caused over 90% mortality (Table 2). In general, the rate of mortality increased with time after exposure to NSP and triplex.

F_1 progeny weevils emerged

Significantly higher number of F_1 progeny weevils emerged from the untreated check (211-240) (Table 4) compared to the other treatments (Table 3). Among the botanical treatments the highest number of progeny (63.2) emerged from the lowest rates of NSP treatment. On the other hand, progeny emergence was less than one individual in case of MTP and triplex, while no progeny has been recorded from the highest rate of MTP.

Percentage grain damaged, weight losses and seed germination

There were no significant differences between the main effects of the rates, botanicals (Table 3) and genotypes (Table 4) in affecting percent gain weight and seed germination. However, there were significant differences among rates and botanicals in causing percent grain damage. The highest grain damage was observed in the NSP treatment. On the other hand, there were significant differences between botanical treatments and the untreated check in percentage of damaged grains and grain weight losses. The amount of grain damage ranged from 36.7-42.8% (Table 4) in the untreated check, while in the botanical treatments the maximum damage recorded was 13.3% (Table 3).

Table 3. Main effects of three botanicals and their rates on the number of progeny weevils emerged, percentages of grain damaged, grain weight losses and seed germination of three maize genotypes.

	Main effect	Neem seed powder rate			Mexican tea powder rate			Triplex rate		
		0.5	1	2	1.25	2.5	5	0.1	0.2	0.4
Progeny weevils emerged	Rate	63.2a	15.6bc	4.5c	1.1c	0.1c	0.0c	0.67c	1.3c	0.1c
	Botanical		27.77a			0.4b			0.69b	
Percentage grain damage	Rate	13.3± 1.9a	5.6± 0.1ab	2.5 ± 0.3b	0.23± 0.1b	0.43± 0.3b	0.33 0.1b	0.36.2b	0.8±0.25 b	0.360.0b
	Botanical		7.13 ± 1.02a			0.33 0.77b			0.51± 0.73b	
Percentage grain weight loss	Rate	1.11a	0.39	0.25a	0.06a	0.05a	0.08a	0.04a	0.09a	0.03a
	Botanical		0.59a			0.06a			0.05a	
Percentage germination	Rate	90.0a	92.96a	93.67a	90.73a	88.3a	91.87a	92.33a	94.0a	92.0a
	Botanical		92.2 ± 0.87a			90.4 ± 1.11a			92.8 ± 1.16a	

Means with the same letter in a row are not statistically significant at $p < 0.05$

Table 4. Mean number of progeny weevils emerged, percentages of grain damage, grain weight losses and seed germination in pirimiphos-methyl treated and untreated check.

Parameters	Genotype code	Pirimiphos-methyl	Untreated control
Progeny weevils emerged	G1	0.33 ± 0.3b	240.3 ± 27.9a
	G2	0.33 ± 0.3b	243.0 ± 39.2a
	G3	0.0b	211.3 ± 25.7a
Percentage grain damage	G1	0.5 ± 0.5b	42.8 ± 5.9a
	G2	0.2 ± 0.2b	36.7 ± 6.4a
	G3	0.0b	38.0 ± 5.9a
Percentage grain weight loss	G1	0.02b	3.0a
	G2	0.04b	2.98a
	G3	0.0b	2.34a
Percentage germination	G1	91 ± 4abc	91.1 ± 1abc
	G2	81 ± 4c	86.7 ± 4abc
	G3	94 ± 1abc	82.2 ± 3bc

Discussion

The present results indicated that the two botanicals, MTP and triplex are effective against the maize weevil. This is in agreement with earlier reports. According to Mekuria (1995), MTP applied at 2 and 4% w/w was comparable to the standard synthetic insecticide pirimiphose-methyl in protecting maize from *Sitophilus* species. Gonzalo *et al.* (2005) reported that among 22 different botanicals tested at different rates, the best results were obtained from MTP at 1.0 and 2.0% (w/w), which caused >90% adult maize weevil mortality. The application of triplex at 4 and 2.5 kg/ton of maize was as effective as the synthetic insecticide (pirimiphos-methyl) at the recommended rate in reducing insect populations by more than 90% after eight months of storage (Girma *et al.* 2008). Many research results on the unprocessed endod are available. Firdissa and Abraham (1999) evaluated endod seed and leaf powder at 5 and 10% w/w, and observed 75 and 74% mortality 7 days after infestation, respectively. According to these authors, both seed and leaf powder treatments caused over 90% mortality after 28 days. Similarly, treatment of maize grain with dry seed powder of endod caused high level of mortality (61-93%) and lower level of progeny emergence in the maize weevil (EARO, 1999).

However, NSP especially at lowest rates did not show remarkable control of weevils, though its efficacy has been proven in different countries. Sutherland *et al.* (2002) reported that several neem kernel extracts exhibited a low contact kill of small rice stinkbug. According to these authors, the formulation NEEM-X, which contains a higher concentration of the active ingredient, azadirachtin, had a very poor performance which caused only less than 5% stinkbug mortality. According to Kivan (2005), a commercial neem insecticide (Neem Azal T/S) applied at a dose of 0.5% did not give significant mortality on both adult and nymphs of Sunn pest during the first 3 days after treatment. This result is to be expected, as azadirachtin is not generally known for its ability to kill insects outright (Sutherland *et al.*, 2002) and may take well in excess of 15 days to do so. Neem is more regarded for its sub lethal and chronic effects on insect pests and it has generally antifeedant activity (Schmutterer, 1988; 1990).

Different researchers have found that differences in kernel hardness (Dobie, 1974; Urrelo and Wright, 1989a; 1989b) or differences in surface relief of different maize hybrids (Tipping *et al.*, 1986; 1988) could affect populations of maize weevils. But the results presented here indicate that the three genotypes differ little in their ability to sustain adult weevils over short durations.

In the present study the findings of significant reduction and prohibition of progeny emergence observed in all rates of different botanicals is inline with the finding of Taponjou *et al.* (2002) who reported that progeny production was completely suppressed in MTP treated grains infested by *S. granaries*, *S. zeamais* and *P. truncates* at the dosage ranging from 1.6% to 6.4%. Abraham (2003) found that NSP at 2%w/w and above completely suppressed progeny emergence. In contrast to previous report the result obtained from the present study revealed that progeny weevils were emerged even from 2% NSP. According to Lale and Abdulrahman (1999), significantly higher numbers of adult cowpea bruchid were emerged from cowpea seeds treated with neem seed powder than neem seed oil at the same amount.

The lower values of weight losses observed in this study corroborate the earlier finding of Golob (1981) who reported that the count and weight method gave consistently lower losses as compared to a standard volume weight method. The rate of seed germination was not affected by the three botanicals. According to Asmare (2002), good germination capacity was observed in sorghum seeds treated with neem seed powder, *Chenopodium anbrosiodes* seed powder and tobacco leaf powder.

Conclusion

From the result it can be concluded that Mexican tea powder and triplex at lower rates (1.25% and 0.1% w/w) can effectively control maize weevil. Neem seed powder did not show an acceptable control of the maize weevil especially at lower rates. At higher rate (2% w/w) like others neem seed powder can also significantly increased adult maize weevil mortality. However, there was an increase in mortality with time in the rates of neem seed powder. Thus users can utilize any of these botanicals at the indicated rates depending on their practical convenience, including availability and cost. Users should avoid continuous use of a particular botanical at lower rates.

Acknowledgments

This work is part of an M.Sc. thesis of the senior author. The World Bank via the Agricultural Research and Training Project of Ethiopian Institute of Agricultural Research funded it. We acknowledge Mekides Kebede, Geta Gelana and Tarike Soressa for their assistance during data collections.

References

Abbott, W.S. 1925. A method of computing the effectiveness of an insecticide. *Journal of Economic Entomology*, 18: 265-267.

Abraham Tadesse. 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. 250 pp.

Abraham Tadesse. 2003. Studies on some non-chemical insect pest management options on farm-stored maize in Ethiopia. Ph.D Thesis, Giessen University, Germany. 246 pp.

Adams, J.M. and Schulten, G.G. 1978. Loss caused by insects, mites and micro-organisms. In: Post-Harvest Grain Loss Assessment Methods. (Compilers: K.L. Harris and C.J. Lindblad) USA: Pp. 83-95. American Association of Cereal Chemists.

Asmare Dejene. 2002. Evaluation of some botanicals against maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Cruculionidae) on stored sorghum under laboratory condition at Sirinka. *Pest Management Journal of Ethiopia*, 6: 73-78.

Beyene Seboka, Benti Tolessa and Abera Deressa. 1997. The impact of post-harvest technology on productivity gains of maize hybrids in Ethiopia. In: J.K. Ranson, A.F.E. Palmer, B.T. Zambezi, Z.O. Mduruma, S.R. Waddington, K.V. Pixely and D.C. Jewell (eds.). Pp. 32-36. Maize Productivity Gains Through Research and Technolgy Dissemination. Proceeding of the Fifth Eastern and Southern Africa Regional Maize Conference, held in Arusha, Tanzania, 3-7 June 1996. CYMMYT, Addis Ababa, Ethiopa.

Bosque-perez, N.A. and I.W. Buddenhagen. 1992. The development of host-plant resistance to insect pests: outlook for the tropics. In: Menken, S .B. J., et al., (eds.). pp. 235-239. Proceedings of the 8th International symposium. Insect-pest Relationships. Kluwer Academic Publishers, Dordrecht,

Boxal, R.A. 1998. Grain-Post-harvest loss assessment in Ethiopia. Report No. 2377. NRI, University of Greenwich. 39 pp.

Dobie, P. 1974. The susceptibility of different types of maize to post harvest infestation by *Sitophilus zeamais* and *Sitotroga cereslella* and the importance of this factor at the small-scale farm level. Centro International de mejoramiento de maizy Trigo, condses 40, Mexico 6 D.F.No.10, 98-113.

EARO (Ethiopian Agricultural Research Organization). 1999. EARO Annual Report 1997/98. EARO, Addis Ababa, Ethiopia.

Emana Getu. 1999. Use of botanicals in the control of stored maize grain insect pests in Ethiopia. In: Maize Production Technology for the future: Challenge and opportunities: Pp. 105-108. Proceeding of the Sixth Eastern and Southern Africa Regional Maize Conference. 21-25 September 1998, Addis Ababa, Ethiopia.

Firdissa Eticha and Abraham Tadesse. 1999. Effect of some botanicals and other materials against the maize weevil *Sitophilus zeamais* Motschulsky on stored maize. In: Maize Production Technology for the future: Challenge and opportunities: pp. 101-104. Proceeding of the Sixth Eastern and Southern Africa Regional Maize Conference, 21-25 September 1998, Addis Ababa, Ethiopia.

Girma Demissie, Addis Teshom, Demissew Abakemal and Abraham Tadesse. 2008. Cooking oils and "Triplex" in the control of *Sitophilus zeamais* Motschulsky (Coleoptera: Curculionidae) in farm-stored maize. *Journal of Stored Products Research, 44 (2008) 173-178.*

Golob, P. 1981. A practical assessment of food losses sustained during storage by small holder farms in the Shire Valley Agricultural Development Project area of Malawi: 1978/79. Report of the Tropical Products Institute (Tropical Development and Research Institute), G154, 47pp.

Golob, P. and Webley, D.J. 1980. The use of plants and minerals as traditional protectants of stored products. Report of the Tropical products Institute G 138, 32 pp.

Gonzalo, S., O. Odette, H. Ruperto and T. Maritza, 2005. Search for plants with insecticidal properties for *Sitophilus zeamais* Control in Stored Corn. *Pesq. Agropec. Bras., Brasilia*, 40: 11-17.

Kivan, M. 2005. Effect of azadirachtin on the Sunn pest, *Eurygaster integriceps* Put. (Heteroptera, Scutelleridae) in the laboratory. *Journal of Central European Agriculture*, 6(2): 157-160.

Lale, N. and Abdulrahman, T. 1999. Evaluation of neem (*Azadirachta indica* A.Juss) seed oil obtained by different methods and neem seed powder for the management of *Callosobruchus maculatus* (F.) (Coleoptera: Bruchidae) in stored cowpea. *Journal of Stored Products Research*, 35: 135-143.

Lale, N. and Mustapha, A. 2000. Potential of combining neem (*Azadirachta indica* A. Juss) seed oil with varietal resistance for the management of the cowpea bruchid, *Callosobruchus maculatus* (F.). *Jouran of Stored Products Research*. 36: 215-222.

Mekuria Tadesse. 1995. Maize storage insect pest status in South Western Ethiopa (Abstract). PP. 24. Proceeding of the Second Annual Conference of the Crop Protection Society of Ethiopia, CPSE 26-27 April 1994, Addis Ababa, Ethiopia.

Schumutterer, H. 1988. Potential of azadirachtin containing pesticides for integrated pest control in developing and industrialized countries. *Journal of Insect Physiology*, 34: 713-718.

Schumutterer, H. 1990. Properties and Potential of natural pesticides from the neem tree, *Azadirachta indica*, Ann. Rev. Entomol. 35: 271-297.

Sutherland, J.P., V. Baharally and Permaul, D. 2002. Use of the botanical insecticides neem to control the small rice stinkbug, *Obalus poecilus*, (Dallus 1851) (Hemiptera: Pentatomidae) in Guyana, *Entotmotropica*, 17: 97-101.

Tapondjou, L., C. Adler, H. Boudal and Fontem, D. 2002. Efficacy of powder and essential oil from *Chenopodium ambrosioides* leaves as post harvest grain protectants against six-stored product beetles. *Journal of Stored Products Research*, 38: 395-402.

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

Tipping, P.W., J.G. Rodriguez, C.G. Poneleist and Legg, D.E. 1986. Feeding activity of *Sitophilus zeamais* (Coleoptera: Curculionidae) on resistant and susceptibile corn genotypes. *Environmental Entomology*, 15: 654-658.

Urrelo, R. and Wright, V.F. 1989a. Development and behavior of immature stage of the maize weevil (Coleoptera: Curculionidae) within kernels of resistant and susceptible maize. Annual Entomological Society of America, 82: 712-716.

Urrelo, R. and V.F. Wright, 1989b. Oviposition performance of *Sitophilus zeamais* Motsch.ulsky (Coleoptera: Curculionidae) on resistant and susceptible maize accessions. *Journal of Kansus Entomological Society*, 62: 23-31.

Wongo, L. 1996. Review of Kenyan Agricultural Research. Volume 11. Post-harvest Technology. 30 pp.