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Combined effect of grain solarisation and oiling on the development of *Sitophilus zeamais Motsch*

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Abstract

The maize weevil (*Sitophilus zeamais* Motsch. Coleoptera; Curculionidae) is one the most important storage pests of maize in East Africa. We investigated the combined efficacy of grain oiling with vegetable oil and 2- hour grain solarisation on *S. zeamais* damage to maize. Maize, Longe 1 variety was treated at dosages of 0, 1, 2, 4 ml per kg of grain, and artificially inoculated with 12- adult *S. zeamais* weevils. Combination of grain oiling and solarisation of grain at 1, 2 and 4 ml per kg significantly reduced weevil emergence (F=3.06, P< 0.001) compared to the singular treatments. Solarised grain had 5.5 ± 0.3% damage compared to less than 1% damage where grain was both solarised and oiled at 1, 2 and 4 ml per kg dosage levels. Oiled and unsolarised maize grain treatments significantly (F= 18.27, P< 0.001) had better percentage viability at 93.0 ± 0.7; 91.5 ± 0.9, 91.3 ± 0.9 at 1,2, 4 ml per kg respectively, compared to 76.5 ± 3.7 for the untreated maize grain. Combined oiling and solarisation provides residual grain protection to maize against *S. zeamais* on maize without compromising quality and provides an alternative management option for the pest.

Key words: Oiling, residual protection, solarisation, *S. zeamais*

Introduction

Globally, a considerable portion of crop yield is increasingly lost due to pests and diseases after harvest. In East Africa, the maize weevil (*Sitophilis zeamais* Motsch Coleoptera; Curculionidae) is, arguably, the most important loss causative factor on stored maize (Muyinza, 1998) with conservative loss estimates at 40% of the harvest in 3-6 months of grain storage (World Bank report, 2011). Small scale resource poor farmers who form the bulk of maize growers in East Africa are usually forced to avoid long term grain storage and revert to selling their crop soon after harvest when prices are lowest, leading to widespread poverty. Technologies that maintain the quality of post-harvested produce can greatly enhance the marketability of maize grain and ensure farmers' access to larger markets. These markets, however, have limits on the acceptable levels of pesticide residues on the crop which makes the development of alternative pest management options of urgent and paramount importance.

In Uganda, the management of storage pests of maize has mainly included use of chemical insecticides such as malathion 2%, pirimiphos methyl + permethrin dust and deltamethrin among others. However, the pesticides are grossly misused by the largely illiterate farmers, mainly through application of wrong dosages resulting from poor interpretation of recommended application rates. Pesticides are also adulterated by unscrupulous traders, which has resulted in insecticide resistance by several species of storage insects in Uganda and elsewhere (Hamacher *et al*., 2002; Pereira *et al.*, 2008). Chemical grain dusts are also usually very expensive, not readily available to farmers and prone to human and environmental toxicity. Cultural methods such as sun-drying of maize to reduce moisture and pest damage are alternative options that have been used in the past with little pest management success (Kestenholz, 2002). An integrated pest management approach could provide the best options to combating this pest problem by offering effective and user friendly alternatives to management of the maize weevil.

Previous studies have shown potential in the use of botanical pesticides for the management of storage pests of grain (Kyamanywa *et al.,* 1999; Agona and Muyinza, 1999). These have included leaf and seed products including *Chenopodium* spp. and tobacco (Kyamanywa *et al*., 1999; Agona and Silim, 1998; Kestenholz, 2002); *Ocimum canum* (Kestenholz, 2002) and cooking oils (Silim, 1999) on bean bruchids and *S. zeamais* among others. Others have reported physical methods including grain heating in a solarisation technique to be effective against *S. zeamais* weevil (Agona and Silim, 1998). This technique however, has been found to leave no residual protection in treated grain implying that the grain can be completely damaged when re-exposed after treatment. Other methods effective on the weevil have been reported to include grain treatment with vegetable oiling (Bekele and Hassanali, 2001; Lui and Ho, 1999).This however, was reported to increase grain rancidity and therefore, needed regular treated grain re-sunning (Khaire *et al*., 1992; Lui and Ho,1999). It is possible that a combination of a more residual grain treatment such as grain oiling and re-sunning treatment regimes such as use of solarisation technique may enhance efficacy of the two treatments and contribute to development of an effective management package against the pest. However, the combined efficacy of these techniques has not been studied before. Therefore, this study was initiated to test the efficacy of alternative maize weevil integrated pest management technologies. Specifically the main objective of the study was to;

i) Identify the combined effect of oiling and solarisation on weevil development and maize grain damage by *S. zeamais*
ii) Identify the effect of grain treatment on viability of treated grain

Materials and methods

Weevil cultures

The weevils used for grain inoculation were obtained from the routine stock cultures maintained in the Entomology laboratory in the National Post-Harvest Programme at Kawanda in Uganda. These are routinely rejuvenated with insects from the wild to ensure that their behaviour is comparable to wild populations. The experimental weevils were cultured at 23-28º C and 55-75% relative humidity. To ensure uniformity of insect ages, adult weevils for use in the experiments were sieved out of the cultures to ensure that the subsequent insect stages are of uniform age.

Grain samples

The experimental maize was Longe 1 variety obtained from farmers' fresh harvests. It was sun-dried to 12-14% moisture content. It was then solarised using previously developed procedure (Agona and Silim, 1998) for 2 hours to remove incipient infestation.

Experimental design

The experiments were set in a completely randomised design. At least, 20 kg of maize grain was weighed from the solarised maize for experimental use. A 200 g sample in 4 replicates was randomly obtained by the quartering method. It was then used to determine the initial damage and % viability values of the grain. Then the rest of the grain was used as follows:

Determination of the combined effect of solarisation and oiling on S. zeamais development

Maize which had previously been solarised was used in this experiment. Vegetable cooking oil (Ufuta bland) largely comprised of palm nut oil was used. It was measured using a micropipette into 5 ml glass tubes in the laboratory. The oil was then mixed with 5 kg of the maize grain at dosage rates of 0, 1, 2 and 4 ml per kg of grain. Four replicates with 200g each were weighed into 300 ml polystyrene containers. These were then covered with aerated lids to ensure adequate grain aeration. Then to each of these lots, 12 adult *S. zeamais* (2-week old) weevils were introduced at an inoculation ratio of 1: 3 male to females. The insects, prior to inoculation had been sexed using sexual dimorphic features. The female *S. zeamais* have distinct features of the rostrum clearly different from males and these were used for their separation (Muyinza, 1998).

The inoculated weevils were left to oviposit for 2 days and then removed. The grain was then re-solarised for 2 hours and replaced into the containers and randomly placed on the shelf in the lab. In addition, a control where grain was completely untreated (neither oiled nor re-solarised) but similarly inoculated with weevils was similarly set up and incubated.

After ten days from the end of oviposition, the oiled grain treatments, apart from the controls were solarised again for 2 hours. Following this, the grain was cooled and restored to each specific treatment container and incubated as before. The treatment samples were monitored every other day starting from 20 days after the end of oviposition for weevil emergence. When weevil eclosion started, they were removed and counted until weevil emergence ceased. After the end of weevil emergence, 100 grains were randomly picked from each container and evaluated for % grain damage.

Determination of grain viability

The percentage viability was determined by randomly sampling 50 grains from four replicates per treatment. Then percentage viability of the grain was assessed following ISTA seed viability methods.

Thus investigative parameters included;

i) initial and final moisture content,
ii) initial and final % viability,
iii) number of emergent adults,
iv) % damaged grain.

Determination of the effect of oiling on S. zeamais development

In this experiment, the samples were not solarised but similarly incubated. The treatments thus included maize grain treatment with vegetable cooking oil at 0, 1, 2 and 4 ml per kg of maize grain.

In each 200 g samples, 12 adult *S. zeamais* weevils were inoculated at a ratio of 1: 3 male to female respectively. These were left to oviposit for 2 days and then removed. A control whose grain was solarised for 2 hours after the oviposition period was also similarly set up. All treatment containers were randomly placed on the shelf in the lab, at ambience, until weevil emergence started. They were then monitored every alternate day until weevil emergence ceased.

Data analysis

Prior to analysis, data involving weevil counts and damage scores were standardised using square root transformation and percentage scores, using arcsine transformation (Gomez and Gomez, 1984). Mean separations were done using one way Analysis of variance (ANOVA1) in MSTATIC package. During mean comparisons, any two means were significantly different, when the difference between them was greater than twice their standard error difference (sed) between them.

Results and discussion

There was a significant variation in mean adult weevil emergence with the treatment (Figure 1) ($F=3.06$, $P< 0.001$). Significantly more adults emerged from solarised and un-oiled grain than from the rest of the treatments (Figure 1). Grain with combined oiling and solarisation treatments at 1, 2 and 4 ml w/w had the least emergent weevils at 1.0 ± 0 respectively, compared to the unitary solarisation and un-solarised treatment; and un-oiled maize which had weevil counts as high as 16.8 ± 6 and 33.5 ± 5 respectively (Figure 1). Combination of increasing oil dosage rates with solarisation from 1 to 4 ml per kg did not lower weevil emergence. However, increase in oil dosage resulted in lower emergencies on oiled and unsolarised grain (Figure 2).

Where grain oiling was done, no weevil eclosion occurred in the first 30 days. The highest cumulative number of weevils was 24 ± 2.4 which peaked at 60 days from untreated controls and the least was $3.6 \pm 0.1$from 4 ml per kg grain treatment (Figure 2). Weevil emergencies increased with time across treatments, but all oiled treatment dosage levels significantly had less emergencies than the solarised grain. At 60 days, -18 ± 4.0 weevils had emerged from the solarised grain without oil treatment. This was significantly more than the emergencies from oiled and solarised maize at 1, 2 and 4 ml w/w respectively (Figure 2) ($P< 0.001$ $F= 3.06$).

Similarly, weevil eclosion increased with time on solarised oiled grain (Figure 3).The highest number of weevils was recorded from the unoiled solarised grain with a peak of 16.3 weevils at 60 days, compared to the oiled and solarised maize treatments at 1, 2 and 4ml w/w where weevil emergence did not exceed 1 at 60 days (Figure 3).

Across all the treatments, a combination of oiled and solarisation grain at 1, 2 and 4 ml, significantly reduced weevil emergence ($F=3.06$, $P< 0.001$) compared to the singular treatments. Solarised and un-oiled grain had a

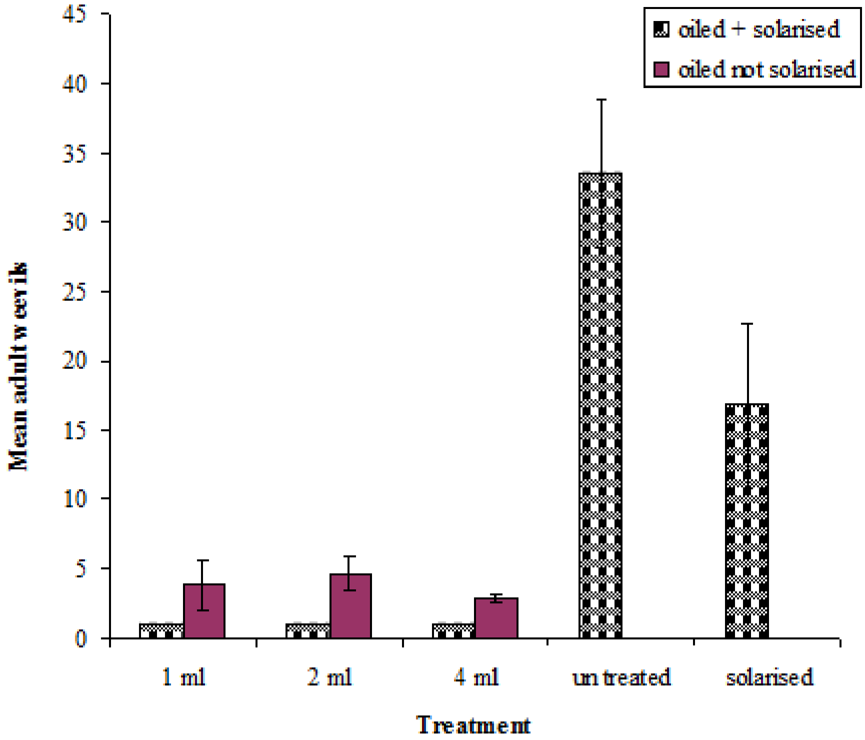

Figure 1. Variation in total adult emergent adults in combined solarised and oiled grain with treatment.

considerably higher number of emergent adults than the combined oiling and solarised samples.

There was a significant reduction in percentage damaged grain among treatments (Table 1). The controls had the highest percentage of damaged grain for both single and combined treatments. The combined solarised and oiled grain at all treatment levels had lower percentage damaged grain than the controls. Among the single treatments, maize treated with oil all at all dosage levels significantly ($F= 19.45$ $P< 0.001$) had lower percentage damage, with highest damage seen on untreated grain. The least damage on unsolarised grain was obtained with grain treated with 4 ml of oil (Table 1).

All oiled and solarised grain were less damaged than the unoiled solarised maize where damage was at 5.5 ± 0.2 % compared to less than 1% grain damage where the combined treatment was used (Table 1).

Grain viability

Oiled and un-solarised grain was significantly more viable than the untreated maize grain (Table 2) ($F= 18.27$, $P< 0.001$). All oiled maize grain treatments were more viable than the control. However, maize treated with oil without solarisation had slightly a higher viability than the oiled and solarised grain (Table 2).

This study revealed that the combined oiling and solarisation resulted in lower weevil emergencies than when the treatments were applied singly. It could be that the vegetable oil provides residual

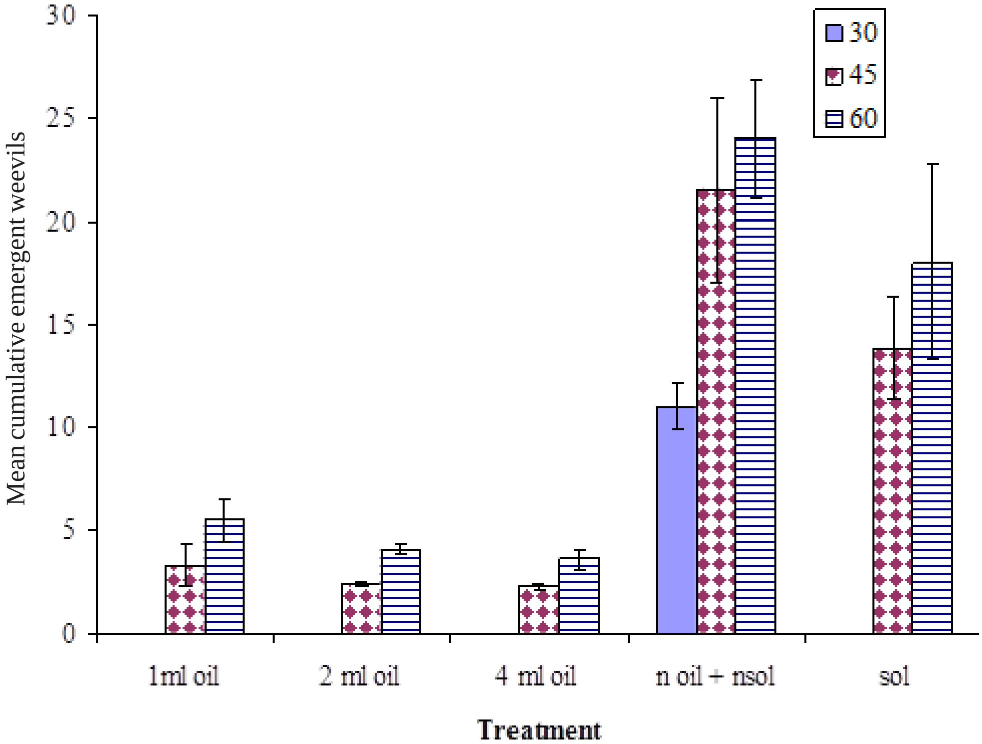

Figure 2. Variation in emergent adult weevils on oiled grain with time (n oil= non oiled grain; nsol= not solarised; sol= solarised grain).

Table1. Variation in mean numbers of damaged grain with treatment

Oil dosage rates	*Mean damaged grains (± se)	
	Solarised	Unsolarised
1 ml	0.3 ± 0.0 a	2.4 ± 0.1 c
2 ml	0.5 ± 0.0 a	2.0 ± 0.2 b
4 ml	0.5 ± 0.0 a	1.3 ± 0.1 a
0 ml	5.5 ± 0.2 b	3.1 ± 0.2 d
Df	15	15
PF=	0.341.25	< 0.00119.45

Data transformed using $(x+1)^{1/2}$ for analysis; se= standard error of the mean

grain protection absent when solarisation is used singly to protect grain. Given the fact that increasing oil dosage rates with solarisation from 1 to 4 ml per kg in combined treatments did not lower weevil emergence, suggests that the effect of grain oiling on *S. zeamais* can be realised on weevil biology at as low as 1 ml oil per kg dosage rates. This means that lower dosage rates of oil in combination with solarisation can be used in *S. zeamais* management treatment. This would

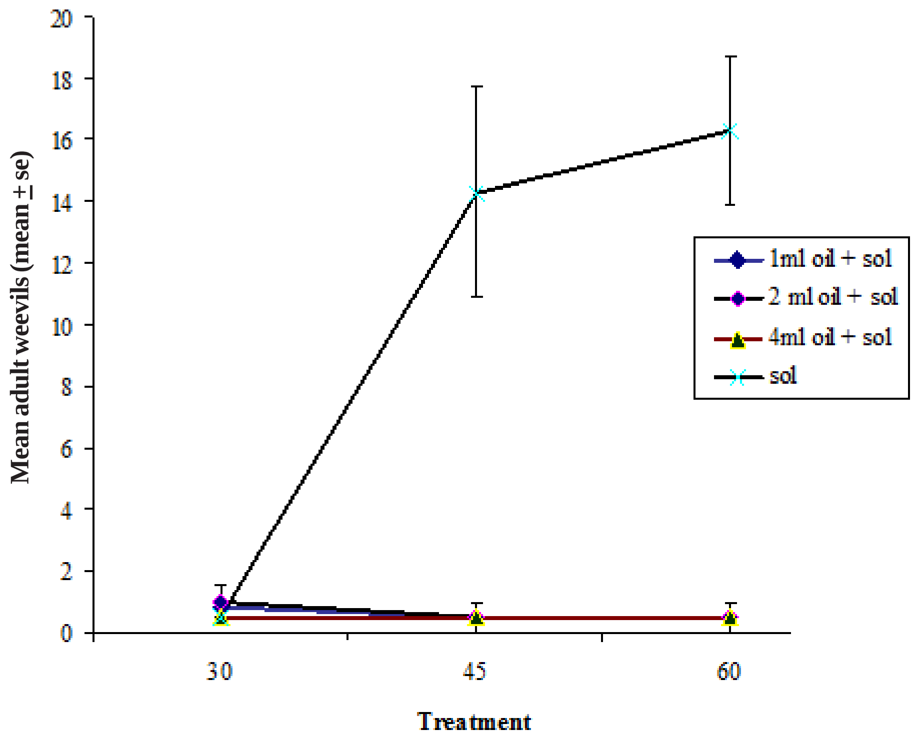

Figure 3. Mean emergent adults with time among treatments of oiled and solarised grain (1 ml oil + sol= 1 ml w/w oil + solarisation; 2 ml w/w oil + solarisation; 4 ml w/w oil + solarisation; sol= solarised grain).

Table 2. Variation in grain viability with treatment

Oil dosage rates	* % viability (mean ± se)	
	Solarised	Un solarised
1 ml	83.3 ± 3.6a	93.0 ± 0.7a
2 ml	82.8 ± 1.4a	91.5 ± 0.9a
4 ml	76.0 ± 4.5a	91.3 ± 0.9a
0 ml	77.5 ± 3.0a	76.5 ± 3.7b
Cv%	4.6	8.8

Cv% = Percentage coefficient of variation ; *Data transformed prior to analysis using arcsine transformation, actual means presented here enhance the efficacy of either techniques in weevil management, and result in lower costs for farmers.

Similarly, there was no significant difference in percentage damage of grain from combined oiling and solarisation treatments at 1, 2 and 4 ml w/w treatments. This could imply that treatment with 1 and 2 ml of oil per kg combined with grain solarisation is equally effective as twice as much oil dosage rates without solarisation (Table 1). It is likely that the oil could interfere with larval development by causing ovicidal mortality. This is in agreement with studies which showed similar effect of oil treatment on bean and pigeonpea bruchids (Agona and Silim, 1999; Bekele and Hassanali, 2001).

This could then result in reduced weevil development and thus lower damage. Other studies on bruchids have indicated similar effects with reports of reduced oviposition (Van Huis, 1991) and high adult and larval mortality especially where vegetable oils such as cotton seed, groundnut, soyabean and mustard oil were used for pigeonpea bruchid management (Silim, 1999). Further, plant oils including oils of spices and aromatic plants have been implicated in the management of *S. zeamais* (Ngamo *et al*, 2001). These were reported to have toxic effects on the weevils and resulted in reduced development and mortality of the weevils. Thus, the efficacy of vegetable oils as shown in the reduced weevil development, is consistent with this finding.

The significantly ($F= 18.27$ $P< 0.001$) higher grain viability when higher oil dosage rates were used for the oiled unsolarised grain, compared to the 1 ml oil treatment, could mean that where oil is used as a single treatment, it could be better to use higher dosages for more grain viability. However, since viability at 1 ml oil dosage was also more viable than the untreated maize, then farmers could weigh the advantage of using higher dosage rates over the advantage of more grain protection in this case.

Also, grain oiling and solarisation resulted in higher grain viability than where grain was untreated (Table 2). This could imply that the treatment can safely be used in protection of farmers' stored seed, especially at small scale farm level. Since the viability of grain was high at dosage rates as low as 1 ml per kg, then grain protection costs can be lowered especially for the resource poor farmers and make it viable even for large grain volumes.

It has been reported that one of the main changes that occur in grains during storage is an increase in free fatty acids. This reaction is often mediated by lipase which releases free fatty acids which may then be rapidly oxidized by lipoxygenase into molecules responsible for bitter and rancid flavours in grain and grain based foods (Abdullah, *et al*., 2000). Although in this particular study we did not conduct rancidity analysis, its known that grain drying reduces development of mould and other moisture related quality loss factors in grain. Thus, combination of grain oiling with solarisation, reduced grain rancidity resulting from oil use. This thus makes it a potential alternative strategy which small scale farmers can adopt in the management of *S. zeamais* on maize.

Conclusions

Combining grain oiling and solarisation reduces damage by *S. zeamais* and maintains the quality and viability of grain. The combination of these treatments can be of use in on-farm storage of maize and enable small scale farmers store maize for as long as 2 months with minimum damage, thus ensuring food security.

In line with this, it is therefore, recommended that;

- Grain oiling with vegetable oil and solarisation combination could be promoted for the on-farm integrated pest management of *S. zeamais.*
- However more studies involving documentation of consumer and market acceptability of the oiled and solarised maize grain should also be conducted.
- The technology could be evaluated for use in the protection of other grain storage pests.

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References

Abdullah, N., Nawawi A. and Othman, I. 2000. Fungal spoilage of starch-based foods in relation to its water activity (aw). *Journal of Stored Products Research* 36:47-54.

Agona J.A. and Silim M.N. 1998. The effect of exposure of beans (*Phaseolus vulgaris*) in a solar dryer on seed viability, cooking time and injuriousness of *Acanthoscelides obtectus* Say (Coleoptera: Bruchidae). *African Crop Science Journal* 6(4): 417-421.

Agona, J.A. and Muyinza, H. (Eds). 1999. Integrated non-chemical control of storage insect pests. In: Proceedings of a training workshop on management of stored product insect pests including the larger grain borer in Rakai district. pp. 1-45.

Agona, J.A. and Silim, M.N. 1999. Proceedings of the 1st conference on stored product insect pests. Their status, coping strategies and control in Eastern, central and Southern Africa. Agona and Silim (Eds.). pp. 1-126.

Bekele, J. and Hassanali, A. 2001. Blend effects in the toxicity of the essential oil constituents of *Ocimum kilimandscharicum* and *Ocimum kenyense* (Labiateae) on two post-harvest insect pests. *Phytochemistry* 57: 385-91.

Gomez, K.A. and Gomez, A.A. 1984. Statistical procedures for agricultural research. pp. 1-680.

Kestenholz, C.C. 2002. Investigations on the biological activity of *Gardenia fosbergii* (Rubiaceae) and *Cassia sophera* (Caesalpiniaceae) against the storage insect pests *Sitophilus oryzae* L. and *Callosobruchus maculatus* F. Ph.D Thesis University of Greenwich UK.

Khaire, V.M., Kachare, B.V. and Mte, U.N. 1992. Efficacy of different vegetable oils as grain protectants against pulse beetle, *Callosobruchus chinensis* L. in increasing storability of pigeonpea. *Journal of Stored Products Research* 28:153-156.

Kyamanywa, S., Bagiire, A. and Agona, J.A. 1999. Comparison of effects of physical and chemical methods of controlling *Sitophilus zeamais* on maize and *Acanthoscelides obtectus* on beans. In: Proceedings of the 1st conference on stored product insects;

their status, coping strategies and control in Eastern, central and Southern Africa. 29th Nov-1st Dec 2, Kampala, Uganda. pp. 38-61.

Liu, Z.L. and Ho, S.H. 1999. Bioactivity of the essential oil extracted from *Evodia rutaecarpa* Hook f. et Thomas against the grain storage insects, *Sitophilus zeamais* Motsch. and *Tribolium castaneum* (Herbst). *Journal of Stored Products Research* 35:317-328.

Muyinza, H. 1998. Evaluation of maize varieties for resistance to the weevil *Sitophilus zeamais* (Coleoptera; Curculionidae) MSc thesis Department of Zoology, Makerere University. 1-60.

Hamacher, L.S., Faroni, L.R.D.A., Guedes, R.N.C. and Queiroz, M.E.L.R.2002. Persistence and activity towards *S. zeamais* (Coleoptera: Curculionidae) of pirimiphos-methyl sprayed at different temperatures on maize. *Journal of Stored Products Research* 38(2):167-175.

Ngamo, L.S., Ngassoum, M.B., Jirovetz, L., Ousman, A., Nukenine, E.C. and Mukala, O.E. 2001. Protection of stored maize against *Sitophilus zeamais* (Motsch.) by use of essential oils of spices from Cameroon. *Meded Rijksuniv Gent Fak Landbouwkd Toegep Biol Wet.* 66(2a):473-478.

Pereira, C.J., Pereira, E.J.G., Cordeiro, E.M.G., Della Lucia, T.M.C., Guedes, R.N.C. and Totola, M.R. 2008. Organophosphate resistance in the maize weevil *Sitophilus zeamais*: Magnitude and behaviour. *Crop protection* 28(2):168-173.

Silim, M.N. 1999. Biopesticides: Their potential in controlling storage pests. In: Proceedings of the 1st Conference on stored product insects; their status, coping strategies and control in Eastern, central and Southern Africa. 29th Nov-1st Dec 2, Kampala, Uganda. pp. 38-61.

The World Bank report 2011. Economic and sector work. Missing food: The case of postharvest grain losses in Sub-Saharan Africa. Report60371-AFR. The International Bank for Reconstruction and Development/ the World Bank. Washington, D.C. USA. pp. 1-95.

Van Huis, A. 1991. Biological methods of bruchid control in the tropics: *A review: Insect Science and its Application* 12:87-102.