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Efficacy of botanical powders and cooking oils against Angoumois grain moth, *Sitotroga cereallela* O. (Lepidoptera: Gelechiidae) in stored maize

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During storage, maize grains are severely destroyed by insects and other pests. One of the most important causes of grain loss in stored maize is the damage caused by Angoumois grain moth, *Sitotroga cereallela* O. A study was conducted to evaluate selected locally available botanical powders and two cooking oils for their effectiveness as grain protectants against *S. cereallela* at Jimma University College of Agriculture and Veterinary Medicine in 2011. The plant powders and cooking oils were compared with untreated control and Malathion super dust as standard control. The experiment was laid-out in completely randomized design with three replications for each treatment. Different dependent variables such as adult mortality, F_1 progeny emergency and grain damage were assessed. The results revealed that there was an increase in adult mortality, decrease in F_1 progeny emergency and grain damage as a result of botanical powders and cooking oils application to maize grains. Among the botanicals, very low mortality of 27.80% was recorded from *Maesa lanceolata* (with LT_{50} of 219.8 days) and *Echinops kebericho* (with LT_{50} of 338.10 days) similar to the untreated control. Cumulative mortality of 39.00% was registered from *Azadirachta indica* bark powder (with LT_{50} of 30.40 days) and *Cympopogon citratus* leaf (with LT_{50} of 171 days) against *Sitotroga cerealella* 20 days after insect exposure to the botanicals. Maximum moths mortality, 94.4%, was recorded from standard control (Malathion) followed by the two cooking oils (77.8%). No F_1 progeny emerged from the grains treated with the two cooking oils similar to the standard chemical over the exposure period of 40 days leading to no seed with hole, minimum weight loss and maximum seed germination percentage (97.30%). Thus, the two cooking oils were found to be most potent bio-insecticides against maize grain moth on par with standard check, Malathion.

Key words: Angomois grain moth, *Sitotroga cereallela*, cooking oils, exposure time, grain damage, maize grains, mortality and plant powders.

INTRODUCTION

Cereals are said to be the dominant source of nutrition for one-third of the world's population especially in developing and underdeveloped nations of Sub-Saharan Africa and South-east Asia. Among the cereals; rice, wheat and maize constitute about 85% of total global production (Sofia et.al, 2009). Maize (*Zea mays* L.) is an important cereal crop in Africa serving as source of food, feed and industrial raw material (Meseret, 2011).

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However, the use value of maize is hampered due to many biotic and abiotic factors both in the field and storage. Storage insect pests are the primary causes of loss for maize grains in storage. Losing crops to insect pests constitutes a great constraint to the realization of food security worldwide. Therefore, in order to meet the food demand for the ever increasing world population, it is necessary to address the issue of maize grain loss to insect pest damage in storage.

Among several insect pests that attack maize in storage, the Angoumois grain moth (*Sitotroga cerealella* Olivier (Lepidoptera: Gelechiidae)) is one of the most serious storage insect pests of maize in Ethiopia (Abraham 1991, 1995, 1997; Emana, 1993). Losses caused to maize grain due to infestation by Angomois grain moth have been increasing along with the greater yields and amount of cereal grains being stored in farmer households. This insect alone can account for over 40% of the total losses in stored grain in some areas (Boshra, 2007). An important factor that contributes to this serious loss of grains is the tendency of the larvae to feed inside the grains, which provides the pest additional protection from direct contact with applied insecticides.

To overcome the problems of insect pests damage in storage, different control measures have been developed and used world-wide and synthetic chemical insecticides have been used dominantly for many years (Tapondjou et al., 2002), but synthetic chemical insecticides cause many problems including high persistence, poor knowledge of application, increasing costs of application, pest resurgence, genetic resistance by the insect and lethal effects on non-target organisms in addition to direct toxicity to users (Bekele et al., 1995, 1997; Bekele, 2002; Hubert et al., 2008; Oni and Ileke, 2008; Udo and Epidi, 2009; Feng-lian et al., 2011). In effect the search for benign storage insect pest management tools such as the use of botanical insecticides by entomologist all over the world has been continued (Shaaya et al., 1997; Emana et al., 2003). African farmers have been using plant products to protect their stored grains for several years (Bekele et al., 1995; Bekele 2002; Tapondjou et al., 2002). The use of different parts of different botanical plants and essential oils in different forms were reported to be determinantal to different storage insect pests (Shaaya et al., 1997; Tunc et al., 2000; Tapondjou et al., 2002). Hence, the current study was designed to test the efficacy of different locally available plant materials and two cooking oils against *S. cerealella* in stored maize.

MATERIALS AND METHODS

Description of the study area

The experiment was conducted at Jimma University College of Agriculture and Veterinary Medicine (JUCAVM). JUCAVM is located 354 km south west of Addis Ababa, the capital city of Ethiopia, at an approximate geographical coordinates of latitude 06°36' N and longitude of 37°12' E at an altitude of 1710 m above sea level. The mean maximum and minimum temperatures of the area are 26.8 and 11.4°C, respectively and the mean maximum and minimum relative humidity are 91.4 and 39.92%, respectively. The experiment was conducted under room temperature in entomology laboratory.

Maize grain used for the experiment

Clean and well sieved maize grain of variety 'BH-660' was used, which was obtained from Nekemte cereal division and distribution enterprise. The seeds were frozen at -6°C for seven days to kill any live insects on and in it. This variety of maize is the most commonly grown maize hybrid developed by the national maize research program based at Bako, Western Ethiopia and it is considered as one of the susceptible maize varieties to insect pests (Abraham and Basedow, 2004). Maize grain not previously treated with any insecticide was adequately dried and used to rear the insects for several generations to obtain uniform population of the test insect, *S. cerealella*. The grains were graded manually and almost only larger grains were used in the study. The grains were cleaned of broken kernels and debris by hand and by using a 4.76 mm round holed sieve.

Collection and preparation of botanicals

Fresh and matured leaves, kernels and barks of *Azadrachta indica*, leaves and flowers of *Tagetus erecta*, fresh leaves of *Chenopodium ambrosoids*, seeds of *Maesa lanceolata*, stems of *Alium sativum*, leaves of *Cymbopogon citratus*, roots of *Echinops kebericho*, oils of *Brassica carinata*, and *Gossypium hirsutum* were collected from different sources and brought to JUCAVM entomology laboratory. *T. erecta* and *C. citratus* were collected from Jimma University campus; while *A. indica* (leaf, bark and kernel) were collected from Melka Werer research centre in Afar region; and *C. ambrosoids*, *M. lancelata*, and *E. kebericho* were collected from its natural habitat of eastern Wollega Zone. *A. sativum* was purchased from super market in Jimma town. *B. carinata* and *G. hirsutum* were brought from Harerghe Fades and Addis Mojo Oil Factory of Eastern Shoa Zone, respectively. The leaves and plant material parts were air and shade dried for 14 days in the laboratory. The dried leaves, kernels and roots were pulverized using a micro pulverizer and were sieved through a 0.25 mm pore size mesh to obtain uniform particle size following the procedures described by Araya (2007). The resulting powders were kept separately in glass containers with screw cap and stored at room temperature until when needed. The amounts of powder mixed with the maize grain were calculated on weight by weight bases of powder/grain weight (w/w) that is, 0.5 g plant materials for 250 g of maize grain seeds (1:500).

Rearing of *S. cereallela*

The initial generations of *S. cereallela* were obtained from maize store culture of Jimma Merkato super market stores with maize grains. This initial population was reared in an incubator in jars at 27°C and 50 to 70 RH in JUCAVM Parasitological laboratory. The established moths were reared on 500 g maize grains in two jars of two liters capacity for 35 days. Then, *S. cerallela* adults were collected gently with locally prepared plastic tube used as an aspirator made of Kenyan Bic pen that is, sealed at one end with nylon sheath cloth to protect the incoming of insects, grain debris and other particles. The central hole of the pen tube was sealed with plastic sheath cover. Then, the insects were pushed down to the rearing jars through the holes that formed on the top part of the rearing jars cover. The insects were left to lay eggs on the clean sterilized fresh maize grains.

Table 1. Description of botanicals (treatments) and their parts used against *S. cereallela* in stored maize grains.

Treatment	Dosage (g or ml)	Local name	Common name	Parts used
Control	-	-	-	-
Malathion dust (5%)	0.125 g	-	-	Dust formulation
Azadrachta indica	0.5 g	Mimi Zaf / Nimia	Neem	leaf
Azadrachta indica	0.5 g	Mimi Zaf / Nimia	Neem	bark
Azadrachta indica	0.5 g	Mimi Zaf / Nimia	Neem	Kernel/seed
Cympopogon citratus	0.5 g	Ajaye	-	leaf
Tagetus erecta	0.5 g	Tej Sar	-	leaf
Alium sativum	0.5 g	Nech Shinkurt	Garlic	leaf
Maesa lanceolata	0.5 g	Kelewa/Abayi	-	seed
Chenopodium ambrosioids	0.5 g	Fara-Gonda	-	leaf
Gossypium hirsutum	0.5 ml	Tit or Jirbi	Cotton	seed oil
Brassica carinata	0.5 ml	Gomenzer	Cabbage	seed oil
Echinops kebericho	0.5 g	Kebericho	-	root

Treatments and experimental design

There were 13 treatments arranged in completely randomized design (CRD) and the treatments were replicated three times. Table 1 shows the detail of the treatments. There were two controls in the treatments (the untreated control and the standard control-Malathion super dust) for comparison. The treatments used were in powder form for the botanicals and oil form for the cooking oils. Each treatment was measured and introduced (mixed with maize grain) in to 250 g of maize grains in each jar. The same day adult insects emerged, 20 for each treatment, were collected from mass rearing jars and introduced to each test jars at the same time to maintain uniformity in age as described by Parugrug and Roxas (2008). The jars were arranged 5 to 10 cm apart on a flat table and left undisturbed at 20 to 25°C for oviposition of adult moths.

Bio-assay procedures

Two hundred fifty grams of healthy disinfected maize grain seeds was put in one-liter glass jars and admixed with 0.5 g powdered leaves, bark and/or root of each test plant. Oils were separately dissolved with 2 ml acetone before mixing it with the maize seed and allowed to evaporate for 2 h. The jar contents (treatments and maize grain) were shaken thoroughly for about five minutes to ensure uniform distribution of the botanical powders and the oils. Then, 20 early emerged adults of almost same aged moths were collected from the previously reared culture of insects in the laboratory and introduced in to each jars. After introduction of the predetermined adult insects in to each experimental jar; adult mortality, F_1 progeny emergency, seed damage and germination percentage was experimented as described below.

Adult mortality test

Adult mortality was assessed on 1, 2, 3, 4, 5, 10, 15 and 20th days after exposure of the moths to the treatments. Adults were considered dead when gently probed with sharp objects and there were no responses. Percent adult mortality was determined as per the method described by Parugrug and Roxas (2008) using the following formula:

$$(\%)\ Mortality = \frac{No.\ of\ dead\ insects}{Total\ no.\ of\ insects}\ x\ 100$$

F1 Progeny emergence test

After 20 days of introduction of adult moths in to the experimental jars, all insects, both dead and live were removed from each experimental jar and the seeds were returned to their respective jar. Thereafter, the newly emerged adult moths (F_1 progeny emergence) were recorded on 21, 22, 23, 24, 25, 30, 35 and 40 days from sieved grains for each treatments replication wise.

Percentage grain damage

Percentage grain damage was calculated on 45th days after adult introduction to each experimental jar by taking samples (111 seeds) of the grains from each jar, numbers of perforated holes were recorded and the following general formula was used to determine the percentage of grain damage:

$$(\%)\ GrainDamage = \frac{No.\ of\ perforated\ grains}{Total\ no.\ of\ grains\ counted}\ x100$$

Percentage weight loss

After weighing the initial and final weight of the grain, percentage weight loss was calculated using the following formula (Ileke and Oni, 2011):

$$(\%)\ Weight\ Loss\ = \frac{Initial\ Weight - Final\ Weight}{Initial\ Weight}\ x100$$

Germination percentage

Germination test was carried out on 111 (18.5% of the total grain)

Table 2. *S. cereallela* cumulative percentage adult mortality and Median Lethal Time (LT_{50}) due to the efficacy of botanical powders and cooking oils

Treatment	Mortality (%)	Median Lethal time(LT_{50}) (days)*	Confidence Interval		Slope[±SE]
			Lower	Upper	
Untreated control	27.8	338.1	-	-	1.17±0.29
Malathion dust	94.4	<1.0	-	-	-
A. indica leaf	61.1	18.8	11.6	54.2	1.34±0.32
A. indica bark	39.0	30.4	16.73	147.9	1.39±0.36
A. indica kernel	50.0	18.2	9.5	140.1	0.89±0.28
C. citratus leaf	39.0	171.0	-	-	0.31±0.26
T. erecta leaf	44.4	49.0	18.4	5623	0.87±0.31
A. sativum stem	33.3	42.1	17.8	1216.6	0.97±0.31
M. lanceolata seed	27.8	219.8	-	-	0.47±0.29
C. ambrosoids leaf	61.1	14.7	9.3	37.1	1.27±0.30
G. hirsutum oil	77.8	<1.0[f]	-	-	-
B. carinata oil	77.8	<1.0	-	-	-
E. kebericho root	27.8	338.1	-	-	0.30±0.30

seed samples randomly taken from each treatments replication wise. The seeds were placed in Petri dishes containing moistened filter paper (Whatman No.1) and arranged in an incubator at 30°C at JUCAVM School of Veterinary Parasitological Laboratory. The number of germinated seedlings from each Petri dish was counted and recorded from seven to 10 days after start. The percent germination was computed (Ogendo et al., 2004) as follows:

$$Germination\ (\%) = \frac{No.\ of\ seed\ germinated}{Total\ Grain\ Sampled}\ x100$$

Data analysis

Data entry and analysis were done using Microsoft Excel and SAS institute 9.2 Soft ware package. To determine the effect of the botanicals and cooking oils on *S. cerelealla* adult mortality, F_1 progeny emergence, holes number per sampled grain, weight loss and percentage germination; one - way analysis of variance (ANOVA) was run using SAS 9.2 software package. When the treatments were found significant, means separation was conducted using Turkeys' studentized (HSD) test at 5% level of significance. United State Environmental Protection Agency (UNEPA) Probit analysis was used to determine Median Lethal Time (LT_{50}). All variables recorded were analyzed according to one-way ANOVA model as follows:

$$Y_{ij} = \mu + T_j + E_{ij}$$

Where, Y_{ij} = is the response, μ = is the general mean effect, T_j = is the jth treatment effect and E_{ij} = is the experimental error.

RESULTS

The results of an experiment conducted to determine the effectiveness of botanical powders and cooking oils against *S. cerelleala* with respect to percentage adult mortality, F_1 progeny emergence, maize grain weight loss, number of perforated maize grain seeds and percentage germination are presented as follows.

Adult mortality (%)

The impact of all plant powders and cooking oils against *S. cereallela* in terms of adult mortality in maize grains was significant (P ≤ 0.05) (Table 2 and Figure 1). After the first 24 h (day one) of exposure of the moths to the treatments, most treatments showed comparable *S. cerellela* adult mortality among each other and the control; however they recorded significantly low adult mortality when compared with standard chemical and the two cooking oils. Standard check chemical, Malathion, gave 94.40% adult mortality over time (day one to 20) where as *G. hirsutum* and *B. carinata* oils gave 77.80% adult mortality. Minimum moth mortality (27.80%) was registered from the untreated control, *M. lanceolata*, *E. kebericho* followed by *A. indica* kernel and *C. ambrosoids* leaf powders both with 33.3% adult mortality. The cumulative adult moth mortality (20 days after moth's exposure) followed similar and increased trend after 48 h of moths' exposure for all the treatments. The cumulative adult moths' mortality was more when compared to 24 h of exposure on 48 h of exposure in all treatments except in the control. Generally, the trend was the same after 3, 4, 5, 10, 15 and 20 days of exposure, showing an increasing percentage adult mortality for botanical powders as time of exposure become longer.

The cumulative percentage adult mortality of *S. cereallela*, on the 20th days after introduction of adult moths remained the same and were maximum from the standard check, Malathion (94.4%) followed by the two cooking oils (77.8%); *C. ambrosoids* and *A. indica* leaf

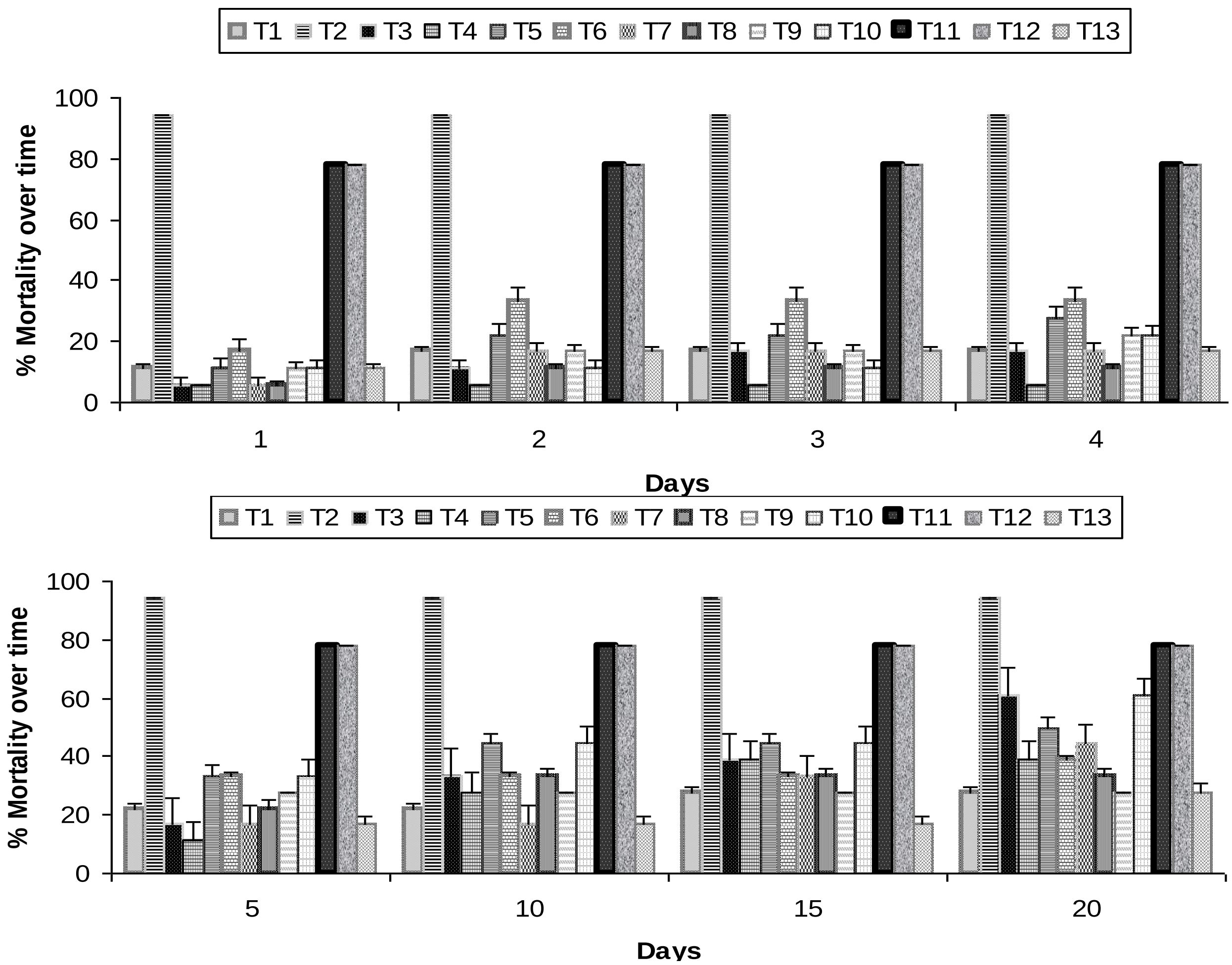

Figure 1. *S. cereallela* adult mortality due to botanical powders and cooking oils in maize grains at different time intervals (days). T_1, Control; T_2, Malathion dust; T_3, *A. indica* leaf; T_4, *A. indica* bark; T_5, *A. indica* Kernel; T_6, *C. citratus* leaf; T_7, *T. erecta*; T_8, *A.sativum* bulb; T_9, *M. lanceolata* seed; T_{10}, *C. ambrosoids* leaf; T_{11}, Cotton seed oil; T_{12}, *Brassica* seed oil and T_{13}, *E. kebericho* root.

(61.1 %); *A. indica* kernel (50%); *T. erecta* (44.4%); *C. citratus* and *A. indica* bark *(*39.00%); and A*. sativum (*33.30%) in that order (Table 2). *M. lanceolata* and *E. kebericho* were poor in their toxicity on *S. cereallela*. The standard check chemical (Malathion) and the two cooking oils progressively reduced the survival potential of the insect pest.

The treatments were found different with respect to the median lethal time (LT_{50}) (Table 2). Among the treatments less than one day was taken to kill 50% of *S. cereallela* for cotton and Ethiopian mustard oil similar with Malathion super dust. Therefore, these two cooking oils are the most potent botanicals against *S. cereallela* in storage. On the contrary, maximum time (338.1 days) was required for *E. kebericho* root powder to kill 50% of *S. cereallela* which was assumed to be the same, based on the probit analysis, with control (338.1 days), *M. lanceolata* (219.8 days) and *C. citratus* (171 days). *A. indica*, *T. erecta, A. sativum* and *C.ambrosoid* with LT_{50} values ranging from 14.7 to 49 days are considered as intermediate ones.

S. cereallela progeny emergency

Mean number of *S. cereallela* F_1 progeny emergency from grains treated with various botanical powders and cooking oils at constant application rate (1 - 500 of treatments to maize grain) was significant (P<0.05) (Table 3). The different plant powders and cooking oils significantly reduced *S. cereallela* F_1 progeny emergency when compared to the untreated control which resulted in an increased F_1 progeny emergency. Up to the 4th days after adult removal (that is, from day 21 to 24), no progeny was emerged from all jars including the untreated control. On 25th days after adult moths introduction (that is, fifth days of introduced adults removal), no maize grain moth was emerged from the

Table 3. *S. cereallela* F_1 Progeny emergence from maize grains treated with botanicals powders and cooking oils at different time interval (days)

Treatments	Time interval after exposure (days)			
	25	30	35	40
Untreated Control	2 (1.58)[a]*	5 (2.35)[a]*	8 (2.92)[a]*	11 (3.39)[b]*
Malathion Dust	0 (0.71)[c]	0 (0.71)[d]	0 (0.71)[d]	0 (0.71)[e]
A.indica leaf	0 (1.22)[c]	0 (0.71)[d]	1 (0.87)[cd]	2 (1.58)[c]
A.indica bark	1 (1.2)[ab]	2 (1.58)[d]	4 (0.87)[cd]	7 (2.74)[c]
A.indica kernel	1 (0.87)[bc]	2 (1.58)[d]	4 (0.87)[cd]	7 (2.74)[c]
C.citratus leaf	1(1.2)[ab]	3 (1.87)[bc]	8 (2.92)[a]	15 (3.94)[a]
T.eracta leaf	1 (1.2)[ab]	3 (1.87)[cd]	6 (2.55)[bc]	14 (3.81)[ab]
A.sativum bulb	1 (0.87)[bc]	4 (2.12)[ab]	9 (3.08)[ab]	15 (3.94)[a]
M.lanceolata seed	1 (1.2)[ab]	4 (2.12)[ab]	9 (3.08)[ab]	17 (4.18)[a]
C.ambrosoid leaf	1 (0.87)[bc]	2 (1.58)[d]	3 (1.87)[d]	4 (2.12)[d]
G. hirsutmn seed oil	0 (0.7)[c]	0 (0.71)[d]	0 (0.71)[d]	0 (0.71)[e]
B.carinata seed oil	0 (0.7)[c]	0 (0.71)[d]	0 (0.71)[d]	0 (0.71)[e]
E.kebericho root	1 (0.87)[bc]	3 (1.87)[cd]	6 (2.55)[bc]	11(3.39)[b]
P value	<0.0001	<0.0001	<0.0001	<0.0001
HSD	0.49	0.55	0.41	0.53
CV (%)	16.63	17.85	12.18	14.6

*Figures in parentheses are transformed data ($\sqrt{x+0.5}$) and means with the same letters within the same columns are not significantly different (P<0.05).

jars that received Malathion dust and the two cooking oils. This was true throughout the experimental period with no adult grain moth emergency from these three treatments indicating the effectiveness of the two cooking oils against *S. cereallela* similar to Malathion dust. In all the other treatments, there was an increasing trend of adult moth emergency from 25 to 40th days of adult introduction indicating the poor effectiveness of these botanicals. Among the botanicals, few moths (only two) were emerged on 40th days after exposure from jars that received *A. indica* leaf powder followed by *C. ambrosoids* leaf powder (four adults).

Maize grain damage by *S. cereallela*

Grain damage by *S. cereallela* was assessed in terms of counting perforated holes, percent weight loss and percent germination reduction caused by adult moth and larvae feeding inside the seeds on 45th days of adult moth introduction to experimental jars. The treatments were significantly different (P<0.05) with respect to the number of perforated seeds, percent weight loss and grain viability (Table 4). Mean numbers of perforated seeds from untreated check were maximum (0.5 out of 10 seeds) and significantly different from all the other treatments except it was on par with jars that received *A. indica* leaf and bark (0.3 holed seeds out of 10 seeds) powder. However, there were no holes observed from grain treated with the Malathion and the two cooking oils indicating their efficacy against *S. cereallela*.

Maximum weight loss was recorded from untreated grains (5.0 %) followed by grains treated with *M. lanceolata* seed powder with 2.0% weight loss. No weight loss was recorded from the two cooking oils on par with the standard check (Malathion). Some treatment effects were significantly different from others after 45 days of grain storage and the untreated grain suffered highly significantly greater grain damage as well as weight loss than grains treated with Malathion 5% dust. The untreated grains had higher percentage weight losses than the treated grains. However, there were no significant differences in weight losses among oils and the standard check insecticide, Malathion affirming the effectiveness of the two cooking oils against *S. cereallela* similar to the standard chemical.

The effect of plant powders on the viability (germination percentage) of maize seeds revealed that there was significant difference (P<0.05) among treatments. Significantly minimum germination percentage of 86.5% was recorded from the untreated seeds. On the other hand, the highest germination percentage was observed from the two cooking oils, *G. hirsutum* and *B. carinata* with 97.3% germination statistically the same with the standard chemical (99.1%). The mean percent germination of other botanicals ranges from 90.10 to 94.6% (Table 4).

The result of simple linear correlation studies among the variables revealed that there existed an association between percent mortality, mean F_1 progeny emergency,

Table 4. Grain hole numbers, percent weight loss and germination of maize grains infested by *S. cereallela.*

Treatment	Hole number/10 seeds	Weight loss (%)	Germination (%)
Control	0.5 (1.0)[a]*	5 (2.3)[a]*	86.5 (9.8)[f]*
Malathion Dust	0.0 (0.7)[d]	0 (0.7)[d]	99.1 (10.5)[a]
A.indica leaf	0.3(0.9)[ab]	1 (1.2)[c]	93.7 (10.2)[cde]
A.indica bark	0. 3(0.9)[ab]	1 (1.2)[c]	93.7 (10.2)[cde]
A.indica kernel	0.2 (0.8)[bc]	1 (1.2)[c]	91.9 (10.1)[de]
C.citratus leaf	0.2 (0.8)[bc]	1 (1.2)[c]	90.1 (10.0)[e]
T. erecta leaf	0.2(0.8)[bc]	1 (1.2)[c]	91.9 (10.1)[de]
A.sativum bulb	0.2 (0.8)[bc]	1 (1.2)[c]	90.9 (10.1)[de]
M.lanceolata seed	0.2 (0.8)[bc]	2 (1.61)[b]	90.1 (10.0)[e]
C.ambrosoid leaf	0.1 (0.8)[cd]	1 (1.2)[c]	94.6 (10.3)[bc]
G. hirsutmn seed oil	0.0 (0.7)[d]	0 (0.7)[d]	97.3 (10.4)[ab]
B.carinata seed oil	0.0 (0.7)[d]	0 (0.7)[d]	97.3 (10.4)[ab]
E.kebericho root	0.2 (0.8)[bc]	1 (1.2)[c]	91.9 (10.1)[de]
P value	0.0001	0.0001	0.0001
HSD	0.63	0.297	2.28
CV (%)	14.55	8.7	0.143

*The numbers inside parentheses are the transformed data (√x+0.5) and means with the same letters within the columns are not significantly different (P<0.05).

Table 5. Pearson correlation coefficients for maize grains infested by *S. cereallela*

	Mortality (%)	Progeny emerged	Hole number	Weight loss (%)	Germination (%)
Mortality (%)	1	-0.40*	-0.73**	-0.52**	0.56**
Progeny Emerged		1	0.48*	0.68**	-0.75**
Hole Number			1	0.56**	-0.61**
Weight Loss (%)				1	-0.87**
Germination (%)					1

*, **Significant at 5% and 1% level of significancy, respectively.

number of perforated holes on the grains; percent weight loss and germination percentage of maize grains infested with the same number of *S. cereallela* (Table 5). Percent adult mortality was inversely and significantly correlated with mean F_1 progeny emergency (r=-0.40*), number of grains perforated (r = -0.73**), percentage weight loss (r=-0.52**) but positively and significantly correlated with germination percentage (r=0.56**). With an increasing trend of moth's adult mortality; there is a decreasing trend of progeny emergency, number of perforated holes on the grains, percent weight loss. On the other hand, an increasing adult mortality is associated with an increasing germination percentage.

DISCUSSION

The effects of different botanical powders and two cooking oils against *S. cereallela* infesting maize grains in storage were evaluated and the result reveals that there is a significant effect of the botanicals and cooking oils on *S. cereallela* mortality, F_1 progeny emergency, percentage damage and germination. The cumulative adult moth mortality was significantly higher over time from the two cooking oils (77.80% mortality) on par with the standard check, Malathion super dust application. This might be because of the fact that the volatile vapors of the two cooking oils were known to cause asphyxiation depriving the insects from getting oxygen. This phenomenon may also be due to the presence of gossypol in *G. hirsutum* and erucic acid in the oil of *B. carinata* leading to the death of the moths. In addition to the existence of eurcic acid in *B. carinata*, it contains high glucosinolates which are the active components found in the oil. This efficacy probably indicates that the oils contain higher content of the active components responsible for the insecticidal properties including the above mentioned compounds. Bamaiyi et al. (2007) reported the application of seed oil and seed powders extracts of *Khaya senegalensis* to stored cowpea prevented *Callosobruchus maculatus* eggs from hatching, larval and pupal development cycle affirming the effectiveness of the bio-pesticides similar to standard chemical Actellic. According to Copping and Menn (2000) application of oils occluded seed funnels leading to the death of developing insects due to lack of oxygen.

Similarly, essential oil extracted from Pistacia lentiscus was found to be toxic to the larvae and adults of red flour beetle (*Tribolium castaneum*) (Bachrouch et al., 2010). Many authors reported the efficacy of various oils against important stored product insect pests (Shaaya et al., 1997; Huang et al., 2000; Tripathi et al., 2000; Singh, 2003; Singh and Yadav, 2003; Wang et al., 2006; Negahban et al., 2007; Shahaf et al., 2008; Srinivasan, 2008). Similarly, a significant protection for maize grains against attack by *S. cereallela* was provided by cooking oils of *G. hirsutum* and *B. carinata* on par with the application of Malathion Super dust. This suggests their protection potential even for other storage insect pests. Feng-Lian (2011), also reported that garlic essential oil, diallyl disulfide and diallyl trisulfide as growth inhibitor of insect pests. Javed et al. (2010) studied and reported the reduction of F_1 progeny production of *S. cereallela* in treated grains with cooking oils because the insects were killed physically by oil coating and impairing respiration through blockage of spiracles thereby resulting in inhibiting immature stages survival or reduced longevity of adult females.

Among the plant powders, extracts of *A. indica* and *C. ambrosoids* leaf powders caused 61.10% *S. cereallela* adult mortality followed by *A. indica* kernel powder (50.00%) over 20 days of exposures. The result observed on the toxicity of *S. cereallela* is in agreement with the study of Javed et al. (2010), who reported that extracts of *Acorus calamus,* sweet flag, *Azadrachta indica* and *Curcuma longa* (turmeric) prepared in petroleum ether, acetone and ethanol exhibited growth inhibitory effect against *S. cereallela*. According to their findings, petroleum ether extract of sweet flag at application rates of 1000, 500 and 250 µg/g and its acetone extract at 1000 and 500 µg/g completely inhibited emergence of *S. cereallela* adults. Zaidi et al. (2003) compared extracts of neem, turmeric and sweet flag as insect repellents against *S. cereallela* under laboratory conditions and found that the acetone-extract of neem was the most effective botanical insecticide. The effect of different cooking oils on *S. zeamais* was reported by Girma et al. (2008) at Bako research center in Ethiopia.

All the botanical powder treatments induced significant reduction in *S. cereallela* F_1 progeny emergence compared to the untreated check although the plant materials vary, in terms of their impact on F_1 progeny emergency, among themselves. Accordingly, powder treatments of *C. ambrosoids, A. indica* leaf, bark and kernel were superior in reducing the production of F_1 progeny among the botanical powders. However, *C. citratus*, *A. sativum*, *M. lanceolata* and *E. kebericho* root powder were less effective compared to other plant powder treatments, which is not significantly different from the control treatment. Moth progeny emergency was significantly lower in *G. hirsutum* and *B. carinata* oils followed by *C. ambrosoids, A.indica* leaf, bark and kernel indicating their toxicity to the insect pest attack. Contrary to this, the highest number of moth emergence (two to three) was recorded in control inflicting maximum grain weight loss followed by *E. kebericho* and *T. erecta*.

The correlation (r) between adult mortality and moth emergence, hole number counted, weight loss was negative and germination percentage was positive. These negative associations indicated that progeny development was drastically hampered at early stage in some treatments. Thereby, less moth emergence and consequently low grain weight loss was recorded. The correlation (r) between *S. cereallela* moths emerged in different treatments and adult recovery from hatched larvae and between moths emerged and grain weight loss caused by developing progeny were positive and significant. The germination test demonstrated that the plant materials tested against *S. cereallela* did not show any visible adverse effects on germination capacity of the grains.

Conclusion

In conclusion, the current findings demonstrate that most of the botanical plant powders and the two cooking oils tested against Angoumois grain moth, *S. cereallela,* had an insecticidal activity. The two cooking oils are potent bio-insecticides against *S. cereallela* similar to the standard synthetic insecticide Malathion. Therefore, these two cooking oils can be used as an alternative to synthetic chemical for the control of *S. cereallela.* Moreover, the local availability of these oils makes them handy for resource poor farmers to use them and reduces cost of maize grain protection. It is believed that, some of these botanical extracts and oils could find a place in IPM strategies, especially where the emphasis is on environmental and food safety in terms of replacing the more dangerous toxic insecticides. However, further research investigation is needed on this regard to confirm the effects of this plant extracts regarding its practical effectiveness under natural conditions to protect the stored products without any side effects. If proved so, there is a scientific rationale for the incorporation of these botanical powders and oils into the grain protection practice of resource-poor farmer to assure food self-sufficiency in Ethiopia.

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