RESEARCH ARTICLE

Evaluation of some botanicals oils for the management of Maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae)

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Manuscript details:

Received: 09.02.2017
Accepted: 21.03.2017
Published : 31.03.2017

Editor:

Cite this article as:
Kifle Gebreegziabiher, Mulatu wakgari and Muluken Goftishu (2017) Evaluation of some botanicals oils for the management of Maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae), *International J. of Life Sciences*, 5 (1): 10-20.

ABSTRACT

The study was conducted at the Plant Protection Laboratory of Haramaya University at a controlled environment of 28±2^{0}C and 75±5% R.H. The objectives were to determine the effective doses of neem seed powder, citrus peel powder and their oil extracts and to evaluate some improved varieties and land races of sorghum for their resistance to maize weevil. Treatments were arranged in CRD replicated four times. Fifty unsexed 3-6 days old maize weevil adults were introduced to each glass jar containing 0.1kg muyra-2 seed. In the first botanical study, neem seed and citrus peel oils each at five rates of 0.25, 0.5, 0.75, 1, 1.5 ml, Malathion 5% dust and acetone treated control were evaluated. The results indicated that, all of the parameters analyzed at all rates of the botanical oils showed significant difference over the acetone treated control except for F_1 progeny emergence and weight loss at 0.25 ml NSO. The botanical oils at rates of 0.75, 1 and 1.5 ml NSO and 1.5 ml CPO per 100 g sorghum produced adult weevil mortality in the range of 91.25-100% and seed protection of 83-100% similar to that of the positive control. For the same botanical oil rates weevil emergence, seed damage and weight losses were statistically at par with Malathion 5% dust. However sorghum seeds treated with botanical oils showed significant reduction in germination compared to Malathion 5% dust. Further research on the botanical oils for long period of time under farmer's storage structure could be necessary.

Key words: Botanicals, maize weevil, sorghum, management.

INTRODUCTION

Sorghum, [*Sorghum bicolor (L.)*] is an important crop ranking fifth in world cereal production with an annual production of 63.89 million tons (USDA, 2015). The most important sorghum producers are the United State, Nigeria, Sudan, India, Ethiopia, Argentina, China, Australia, Burkina and Mali (USDA, 2015). Africa has become the leading sorghum producer with an average annual production of greater than 25.6 million tons of seed and the crop covered larger area than other continents (USDA, 2015). Ethiopia is the third largest producer of sorghum in Africa next to Nigeria and the Sudan with a contribution of about 12% of annual production (Wani *et al*., 2011; USDA, 2015). Sorghum is the third most important crop after teff and maize in area and the second in total production next to maize in Ethiopia (CSA, 2014). Sorghum is used for human nutrition all over the world, but mainly serves as a staple food for millions of people in Africa and Asia (Gabisa and Grenier, 2005). In Ethiopia, one third of the cereal diet comes from sorghum, and it plays an important role for making *injera* next to tef (Asfaw, 2012).

The stored sorghum is attacked and damaged by a number of pests that lead to qualitative and quantitative deterioration. Insects are major post harvest pests of crops both at the farmer and consumer level in the tropics, including Ethiopia. Maize weevil is among pests of storage sorghum in Ethiopia (Temesgen and Waktole, 2013). Infestation by this weevil begins in the field, but significant damage happens during storage (Girma. *et al*., 2008; Baidool *et al*., 2010). Damage by *S. zeamais* causes food loss, increased poverty, and lower nutritional values of seed, increased malnutrition, reduced weight and market values (Temesgen and Waktole, 2013). Under traditional storage facilities in Ethiopia heavy infestation of *S .zeamais* can cause weight losses range 41-80% on maize and sorghum seed (Waktole and Amsalu, 2012).

Orange *(Citrus sinensis* L.) which is widely cultivated in subtropical regions is an evergreen shrub or tree belonging to the family Rutaceae. It is a very important plant that possesses antioxidants, antibacterial, antifungal, anticarcinogenic, anti-ulcer, anti-anxiety, antidiabetic and anti-inflammatory properties (Milind and Dev, 2012). Essential oil extracted from orange peels is known to have toxic, feeding deterrent and poor developmental effects on maize weevil, lesser seed borer and rice weevils (Tripathi *et al.,* 2003). Zia *et al.* (2013) reported that, *C. sinensis* oils are found very successful against *T. castaneum* even at lower concentrations. Essential oils of *C. sinensis* are used as seed protectants due to its fumigant effect, topical toxicity, antifeedant and repellent activity (Muhammad, 2009). The main component of citrus peel oils is limonene having basic biocidal properties against insect pests such as maize weevil and mosquitoes (Sameeh *et al.,* 2004).

Neem is known for its "bitter taste" due to the principal active ingredient azadirachtin, which is the most active. It possesses antifeedant, repellant, growth disrupting and larvicidal properties against a large number of pests (Mathur, 2013). The toxicity of neem to stored products insects is attributed to the presence of many chemical ingredients, such as triterpenoids, which includes azadirachtin, salanin, meliantriol (Ileke and Oni, 2011).

Essential oils extracted from neem have insecticidal activities against storage pests (Palacio *et al*., 2009). Many of these oils have also shown high oviposition and growth inhibitory activities (Tripathi *et al*., 2000). Volatile compound diallyl disulphid isolated from neem have potent toxic, fumigant and feeding deterrent activities against stored seed pests, such as *S.zeamais*, S*. oryzae* and *Tribolium castaneum* (Koul, 2004). Volatile constituent, di-n-propyl disulfide extracted from seeds of *A. indica* is toxic, decreased the growth rate and dietary utilization, when applied as a fumigant to *T. castaneum* adults and larvae and *S. oryzae* adults (Abd El-Aziz and E- Shadia, 2001). Neem kernel oils applied with the concentration of 10 ml/kg maize resulted in 100% of mortality to adult maize weevil one week after application and no progeny weevils emerged from the treated maize (Abrham and Basedow, 2005). Neem seed kernel extracts can reduce African rice gall midge damage in a similar way with plots treated with synthetic pesticide, carbofuran and increases the fertility of the soil (Ogah and Ogbodo, 2012). In the current study, the experiment was carried out to provide data on botanicals for maize weevil management program aimed at reducing damage by *S. zeamais*. Therefore, the objective of the study was;

To determine the effective doses of neem seed (*Azadirachta indica*) and sweet orange peel (*Citrus sinensis*) oil extracts against *S. zeamais.*

MATERIALS AND METHODS

Description of Experimental Site

The study was carried out in the Plant Protection Laboratory of Haramaya University.

Establishment of Maize Weevil Culture

Maize weevil, *S. zeamais,* was reared on a sorghum variety to obtain similar aged weevils for the botanical and resistance screening experiments. Twenty kilogram seed of sorghum variety, Muyra-2 was collected from Haramaya University Sorghum Improvement Research Program. The seeds were cleaned to remove seeds with visible damage symptoms. The cleaned seeds were disinfested by keeping them in a deep freezer at -20 ± 2 °C for two weeks to eliminate any potential field and storage infestation. The seeds were then transferred to plastic bags and kept at rearing room conditions for two weeks (Fikremariam *et al.,* 2009; Muluken and Ketema, 2014). Then, unsexed maize weevil (*S. zeamais*) were collected from farm management store and were reared on the clean and disinfested sorghum seeds (Muyra-2) in ten glass jars, each jar with 2 L capacity. Each jar was contained 500 g seeds to which 100 adult weevils were introduced. Subsequently, the jars were covered with muslin cloth and fixed with rubber band to prevent escape of weevils and to allow aeration. The infested seeds were kept in an incubator adjusted at 25±2^{o}C (Fikremariam *et al*., 2009). Ten days after oviposition, all parent weevils were removed from each jar and the seeds were kept at the same experimental conditions of the incubator. Starting 40 days after introduction of weevils in each plastic container, the emerged progeny weevils were removed daily and transferred to fresh seed until the emerged progenies reached 1000 first generation weevils. The insect cultures used for the experiment were multiplied from the first generation weevil reared in ten glass jars of 500g sorghum seeds to obtain uniform population having 3-6 days aged adult *s.zeamais* for the experiment.

Collection and Preparation of Botanicals

Fresh and matured orange fruit (*C. sinensis* L.) and neem (*A. indica*) kernels were collected from Dire Dawa. The orange fruit of the variety Valencia was peeled. The collected orange peel and neem kernel were dried under shade in Plant Protection Laboratory of Haramaya University.

Preparation of Neem Seed and Citrus Peel oils

The dried peels and kernels were ground separately into powder using High Speed Smashing Machine and were sieved through 0.25 mm pore size mesh sieve to obtain uniform particle size powder. Essential oils of orange fruit peel (*C. sinensis*) and neem seed (*A. indica*) were isolated from the prepared powders by Soxhlet's extraction apparatus. From each of the botanicals 30 g powders were weighed and transferred to clean thimbles and the thimbles were covered with defatted cotton. The thimbles containing the powders were placed in an extractor and were fixed to the condenser of the oil extraction apparatus. The flasks were fitted to the extractor after adding sufficient oil solvent chemical petroleum ether. So that the extracted oil mixed with the solvent was collected within the flask. The extraction period was 8 hours for one cycle extraction until it began to siphon off. The thimbles and the flasks were removed from the extraction apparatus after 8 hours of oil extraction. The residues that remained within the thimbles were discarded, whereas the oils of the some botanical were collected within the flasks. These extracted oils were separated from the solvent petroleum ether using Rotary Evaporator and stored in a refrigerator until the experiment started (Dawit and Bekele, 2010).

Treatment Application

The amounts of oils mixed with the sorghum variety Muyra-2 seeds were calculated on volume by weight (V/W) basis. The oil extracts of *C. sinensis* and *A. indica* at rates 0.25, 0.5, 0.75, 1 and 1.5 ml per 0.1 kg Muyra-2 were prepared and diluted with 2 ml acetone in glass jar (10 ml capacity). Then the oil was thoroughly mixed with acetone to ensure even distribution. The diluted oils were added to 0.1kg of sorghum seed contained in the glass jar and thoroughly mixed with the sorghum seeds by shaking using a glass rod for 5 minutes to adequately coat sorghum seeds with oil extracts. The plastic jars were uncovered to allow the solvent to evaporate for 2 hours (Fekadu *et al*., 2012). Synthetic chemical Malathion 5% dust was used at the recommended rate of 0.5 g/kg as standard check and the acetone treated check in which neither botanical nor chemical insecticide was applied.

Fifty unsexed and newly emerged adult maize weevils were placed in each treatment and were placed at 28±2 ^{0}C and a relative humidity of 70±5% in an incubator at optimal condition for weevil growth and multiplication (Tadele *et al*., 2010). The glass jars were covered with muslin cloth and fixed or tied with rubber band to allow sufficient ventilation and to prevent escape of the weevils. Prior to the start of the experiment, glass jars that were used for the experiment were heat sterilized in an autoclave at 60 °C for three hours to kill all insects and fungal spores that might have come with them. The experiment was arranged in a completely randomized design (CRD) with four replications.

Data Collected

Effect of botanical oils on adult weevil mortality and F_1 progeny emergence

Parent adult mortality was recorded at 1, 7, 14, 21 and 28 days after treatment application, where dead insects were removed and counted. Twenty eight days after infestation, the remaining adult weevils were removed and the numbers of live and dead insects were counted. The assessment periods were selected based on earlier reports of (Dobie, 1974) and the treatments were retained under the same conditions to assess the F_1 progeny. Starting from the date of removal of parent adult weevils, emergence of F_1 progeny weevils were counted and removed daily until 70 days. This period was found for the sufficient completion of adult F_1 progeny emergence.

Seed weight loss

Seventy days after treatment application, 1000 seeds were randomly taken from each treatment and were separated into damaged and undamaged categories. The seeds were separately counted and weighed. Percentage weight loss was calculated using count and weight method for each replication of all the treatments (Adams, 1976) .

$$\text{Weight loss} = \frac{(Wu*Nd)-(Wd*Nu)}{Wu*(Nu+Nu)} \text{ X100}$$

Where:
Wu = Weight of undamaged seed,
Nu = Number of undamaged seed
Wd = Weight of damaged seed,
Nd = Number of damaged seed

Seed damage

The amount of seeds damaged was estimated by converting the proportion of damaged seeds (holed seed) from the total number of sample seeds in each replication.

$$\text{Percent damage} = \frac{\text{Number of damaged grains}}{\text{Total number of grain}} \text{ X100}$$

Percent Protection of Treatments

The effectiveness of different treatments in protecting the seed was calculated using the formula employed by (El-Ghar *et al.*, 1987).

$$\text{Percent protection} = \frac{\text{Total F1 progeny in control - Total F1progeny in treatment}}{\text{Total F1 progeny in control}} \text{ x 100}$$

Treatment effects on seed germination

Germination test was carried out at the end of the experiment. One hundred seeds were randomly taken from each replicate of the trial and were treated with 1% sodium hypochlorite (Chlorox) solution for one minute and rinsed with distilled water for another one minute to remove fungal contamination to the germinating seeds. Then the seeds were placed on moist filter paper in germination box and kept at room temperature and after ten days the number of germinated seedlings from each germination box was counted and recorded. The percent germination was computed using the following formula employed by (Fikremariam, 2009).

$$\text{Germination (\%)} = \frac{\text{NG x 100}}{\text{TG}}$$

Where NG = number of seeds germinated and TG = total number of seeds tested in each Petri dish.

Statistical Analysis

Adult weevil mortality data in each replication was expressed as a percentage of the total number of adult weevils introduced. Mortality data were corrected for control mortality using Abbott's correction formula (Abbott, 1925).

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

Where CM is corrected mortality, T is mortality in treated seed and C is mortality in untreated seed (acetone treated and untreated check). Damaged and germinated seeds were expressed as a percentage of the total number damaged seed per total number of sampled seeds in each replicate. Weight loss data was also expressed in percentage using the equation above. Percentage mortality, damaged seed, germination and percentage protection data were arcsine or angular transformed. The number of F_1 progeny weevils emerged was logarithmic transformed, while percentage weight loss was square root transformed prior to statistical analysis to alleviate the variances. The median development time and susceptibility index data were not transformed. The analysis of variance (ANOVA) was done using SAS version 9.00 (SAS Institute Inc., 2002) at 1% level of significance. Treatment mean separation was accomplished by the Student Newman Keuls Test (SNKT) to determine difference among the means of the treatments. Student Newman Keuls test is appropriate to all possible pair mean comparison procedure for large number of experimental treatments. Correlation analysis was done among the variables using the SAS at 1% level of significance.

RESULTS AND DISCUSSION

Effect of Botanical Oil Extracts on Parent Adult Weevil Mortality

The citrus peel oil (CPO) and the neem seed oil (NSO) treatments showed significant difference from the 7th day up to 28 days after treatment application over acetone treated control (Table 1). Superior results were obtained with CPO on 14 to 28 days after treatment; similar result was obtained with NSO treatments on 7 days to 28 days after treatment application. The standard check Malathion 5% dust resulted in 100% adult weevil mortality within 24 hours after treatment application.

Twenty four hours after treatment application, all the NSO treatments except the lower rate (0.25 ml) caused significantly higher adult weevil mortality compared with acetone treated control. However, all the treatments of CPO were not different from acetone treated control. Among the botanicals 1.5 ml NSO resulted in 94% adult weevil mortality comparable to the Malathion 5% dust. The result indicated that, NSO acted faster than CPO. Similarly, Adarkwah and Obeng-Ofori (2010) reported that wheat seeds treated with higher neem oil resulted in higher mortality of *T. castaneum* 24 hours after treatment than the acetone treated control; however at the lower rate (0.1% per 0.5 kg seed) were not different from the control. However, Nwaehujor and Olatunji (2011) found that at 0.1, 0.2 and 0.3 ml/ 0.05 kg cowpea seeds treated with ethanolic crude oil extract of orange peel recorded higher mortality than the acetone treated control on *Callosobruchus maculates,* Bruchidae after 24 hours. Similarly, Dawit and Bekele (2010) worked on essential oil of orange peel at rates of 0.03 g, 0.15 g and 0.75 g/0.25 kg on haricot bean and caused that 21.14, 26.07 and 47.89% adult mortality on *Zabrotes subfasciatus*, respectively 24 hours after treatment.

Seven days after treatment applications, all the botanical treatments were significantly different from the untreated control. NSO at the rate of 1 ml and 1.5 ml caused 100% adult weevil mortality, while 0.75 ml NSO and 1.5 ml CPO caused 86.93 and 76.38% mortality, respectively. Mortality of *S. zeamais* increased with the increase in the rate of essential oils and exposure time. Similarly, Abrham and Basedow (2005) found that the rate of *S. zeamais* mortality is 100% on 1 kg of maize treated with 10 ml of NSO after one week. Wanyika *et al*. (2009) found highest maize weevil mortality on the 3rd and 4th day after NSO application and increase in activity with the increasing concentration and exposure time. Dawit and Bekele (2010) reported that essential oils of orange peel at rates of 0.03, 0.15 and 0.75 g/0.25 kg of haricot bean resulted in higher adult mortality of *Z. subfasciatus* after 96 hours of exposure time.

Fourteen days after treatment application, the adult weevil mortality in all the treatments was significantly higher than the untreated control (Table 1). Adult maize weevils' mortality was 100% at 1, 1.5 ml NSO and 1.5 ml CPO. The lowest adult maize weevil mortality was recorded at 0.25 ml NSO and CPO. Similar trend was observed at 21 days after treatment application. Adult maize weevil mortality was increased due to NSO and CPO, but the rate of increase due to CPO treatments were higher than that of NSO at 0.25, 0.5, 0.75 and 1 ml. Adarkwah and Obeng-Ofori. (2010) reported that mortality of *T. castaneum* decreased 20 days after treatment, except for the highest doses of 0.059, 0.118 and 0.175 ml NSO per 0.5kg wheat.

Twenty eight days after the treatment application, adult maize weevil mortality was highly significant ($p<0.01$) difference over the acetone treated control (Table 1). Adult maize weevil mortality was 100% on sorghum seeds treated with 1 and 1.5 ml NSO and with 1.5 ml CPO, followed by 91.25% with 1 ml CPO and 0.75 ml NSO which was statistically at par with Malathion 5% dust. The lowest mortality was recorded from 0.25 ml NSO next to the Acetone treated control. The mortality of maize weevil increased with the increase in both botanical types and exposure time. The rate of increase in *S. zeamais* mortality was lower on both CPO and NSO on 28 days after treatment application. This reduction in adult maize weevil mortality was in agreement with the findings of Adarkwah and Obeng-Ofori (2010) who reported significant reduction in effectiveness of neem oil 30 days after treatment even at highest dosages. However, Emeasor and Okori (2008) reported that insecticidal strength of CPO on the mortality of maize weevil increases with the increase in length of storage period. Some botanical oils are potent against adult weevils in a concentration dependent manner (Asawalam *et al*., 2006).

The substances that result in the mortality of maize weevil were different among the NSO and CPO. The toxicity of CPO may be attributed to d-limonene (Sharaby, 1988; Dawit and Bekele, 2010). Also, the essential oil vapors from citrus dried peels exhibited a variable toxic action and strong fumigant toxicity against the *Z. subfasciatus* (Dawit and BeKele, 2010). Lokanadhan *et al.* (2012) reported that neem products act as antifeedant. When an insect is hungry, it wants to feed but if the food material is treated with neem product the presence of azadirachtin, salanin and melandriol causes an antiperistaltic wave in the alimentary canal of the insect. This phenomenon produces something similar to vomiting sensation in the insect. The insect does not feed on the neem treated surface and ability to swallow is blocked Because of this sensation which results in death.

Effect of Botanical Oils on Emergence of F_1 Progeny and Seed Protection

Significantly higher and more number of F_1 progeny weevils emerged from the untreated control than oil treated seeds, except at the lower rate of NSO at 0.25 ml (Table 2). F_1 progeny was emerged from all rates of NSO, except when seeds were treated by 1 and 1.5 ml/0.1 kg sorghum seeds which was the same as Malathion 5% dust. The highest F_1 progeny (504.5) was emergence on 0.25 ml NSO statistically at par with acetone treated control. F_1 progeny was emerged at all rates CPO, but showed significant variation among the rates. In the highest dose 21 weevils/0.1 kg sorghum seeds were emerged. In the lowest dose of 0.25 ml CPO, (358) F_1 progeny weevils emerged which was significantly higher than the rest rates of CPO. So for complete control of F_1 weevil emergence, the rate of CPO should be higher than that of 1.5 ml/0.1 kg of sorghum seed. However, NSO at 1 ml/0.1 kg seed was enough for complete inhibition of F_1 weevil emergence. Generally, the study showed that as the amount of the botanical oil extracts increased the F_1 progeny emergence decrease. Girma (2006) reported that significantly more F_1 progeny weevils emerged in 0.2 kg maize seeds treated with NSO at the lower rate (1%) than in the highest dose (2%).

On the daily progeny emergence count, there were very few dead F_1 progeny weevils on the 1.5 ml CPO, (1 and 1.5 ml) NSO treatment; but zero on the rest of the treatments. This indicated that the active ingredients of the NSO and CPO reached the site of action gradually and paralyzed the newly emerged progenies and the potency of both types of botanical oil extracts decreased with increase in the period of storage. Late emerged F_1 progeny weevils were passive in movement activity, smaller in size and more reddish in color than that of the early emerged weevils.

Table 1 Effects of botanical oil extracts on parent adult maize weevil mortality

Treatment	Rate (g or ml /0.05kg)	Parent adult mortality after treatment application (%)				
		1 DAT	7DAT	14 DAT	21DAT	28 DAT
CPO	1.50 ml	2.5^{ef}	76.4^{c}	100^{a}	100^{a}	100^{a}
	1.00 ml	1.5^{ef}	27.1^{d}	60.7^{c}	85.0^{b}	91.3^{b}
	0.75 ml	1.0^{ef}	11.1^{ef}	38.3^{d}	62.2^{c}	76.0^{c}
	0.5 ml	0.5^{f}	6.0^{fg}	20.9^{e}	44.6^{d}	59.0^{d}
	0.25 ml	0.0^{f}	2.0^{h}	7.1^{f}	16.1^{e}	18.0^{e}
NSO	1.50 ml	94.0^{b}	100^{a}	100^{a}	100^{a}	100^{a}
	1.00 ml	22.0^{c}	100^{a}	100^{a}	100^{a}	100^{a}
	0.75 ml	10.5^{d}	86.9^{b}	90.8^{b}	90.7^{b}	91.3^{b}
	0.50 ml	4.0^{e}	12.6^{e}	16.3^{e}	18.7^{e}	20.8^{e}
	0.25 ml	1.0^{ef}	4.5^{gh}	5.6^{f}	6.2^{f}	7.1^{f}
Malathion 5% dust	0.05 g	10^{a}	100^{a}	100^{a}	100^{a}	100^{a}
Acetone treated	2 ml	0.0^{f}	0.0^{i}	0.0^{g}	0.0^{g}	0.0^{g}
CV		16.2	6.6	5.2	5.7	6.6
SE		11.0	7.6	6.8	9.6	14.3

Means in columns with same letter are not significantly different at α = 0.01. Mean separation was analyzed by SNKT; SE, Standard Error; DAT, Days after treatment; CPO, Citrus peel oil; NSO, neem seed oil.

Table 2 Effect of botanical oil extracts on F_1 progeny emergence and (%) protection

Treatment	Rate(ml or g/0.1 kg)	F_1 progeny	Percentage protection
CPO	1.50 ml	20.5[e]	96.6[b]
	1.00 ml	103.8[d]	83.1[c]
	0.75 ml	131.8[d]	78.6[c]
	0.5 ml	217.8[c]	64.6[d]
	0.25 ml	358.3[b]	41.7[e]
NSO	1.50 ml	0.0[f]	100[a]
	1.00 ml	0.0[f]	100[a]
	0.75 ml	27.0[e]	95.7[b]
	0.50 ml	341.8[b]	44.4[e]
	0.25 ml	504.5[a]	17.9[f]
Malathion5% dust	0.05 g	0.0[f]	100[a]
Acetone treated	2.00 ml	614.8[a]	0.0[g]
CV		3.3	3.5
SE		0.003	4.3

Means in columns with same letter are not significantly different at α = 0.01. Mean separation by SNKT.

This could be due to growth regulating substances present on botanical oil extracts that affect the normal physiological growth of maize weevil. This condition is consistent with the investigation of Lokanadhan *et al.* (2012) who reported that neem seed extracts contain azadirachtin, which inhibits the development of immature insects. Temitope (2014) reported that in addition to the mortality effects, CPO reduced the biological activity of the insects and attributed to the deleterious effect on the normal physiology of the insects.

The sorghum variety, muyra-2 seeds treated with NSO and CPO were significantly protected from weevil emergence over the untreated control (Table 2). NSO at 1 and 1.5 ml NSO were 100% protected from weevil emergence the same as Malathion 5% dust. The lowest dose 0.25 ml NSO resulted 17.39 % protected from weevil emergence. CPO at 1.5 ml caused 96.6% protected from weevil emergence, but the lowest dose 0.25 ml CPO showed 41.72% of protection from F_1 progeny emergence. NSO more protected from F_1 progeny emergence than CPO at 0.75,1 and 1.5 ml, whereas, percentage protection by NSO extracts was less that of CPO extract at 0.25 and 0.5 ml. Generally, the percentage seed protection with NSO and CPO extracts from F_1 progeny emergence increased as the dose of the botanical oils increased. This result agrees with the finding of Dawit and Bekele (2010) who reported that CPO at the rates from 0.03 to 0.75 ml/0.25 kg of haricot bean was effective as pirimiphos-methyl on the reduction from *Z. subfasciatus* F_1 progeny emergence.

Effect of Botanical Oils on Seed Weight Loss, Damage and Germination

The plant oil extract treatments showed significantly decreased percentage of seed weight loss, damage and germination than the untreated control, except the lowest rate of 0.25 ml NSO in seed weight loss (Table 3). Among the NSO rates used in the experiment, the lowest weight loss was recorded from seeds treated with 0.75, 1 and 1.5 ml NSO equally with Malathion 5% dust. However, the highest weight loss was recorded from the lowest rate of 0.25 ml NSO statistically at par with the acetone treated control. Percentage weight loss on CPO was recorded from all treatments, but showed significant variation among the rates. In the highest dose of 1.5 ml CPO, weight loss was 0.28% statistically similar to the Malathion 5% dust. The lowest dose 0.25ml CPO showed 5.86% weight loss. This was in accordance with the findings of Dawit and Bekele (2010) who reported that essential oils of orange peel reduced seed weight loss in *Z. subfasciatus* even at lower dose than the standard check pirimiphos-methyl. The result indicated that 1 NSO and 1.5 ml CPO were enough to safe storage of sorghum seed for 70 days.

The percentages of damaged seed on NSO and CPO treated seeds were significantly lower than in the untreated control (Table 3). There was no damage on 1 and 1.5 ml NSO treated seeds equal to the Malathion 5% dust. The highest seed damage (25.5%) was recorded on 0.25 ml NSO treated seeds. Seed damage was recorded from all the CPO treatments, but had significant variation among the CPO doses. Seed damage was lower (1.1%) was recorded on 1.5 ml CPO. The highest seed damage was recorded from 0.25 ml CPO with 14.57%. NSO at 1 ml and CPO above 1.5 ml per 0.1kg sorghum variety (Muyra-2) were required for Safe protection from maize weevil damage. Similarly Emeasor and Okorie (2008) reported that after treating 0.05 kg maize seed with 100 and 25 mg orange rind oil resulted 2.5 and 29.6% damage, respectively, after 60 days of application. Seed weight loss and damaged were lower due to NSO treatments than CPO at the higher rates of 0.75, 1 and 1.5 ml, while at the lower rates of 0.25 and 0.5 ml CPO was lower than NSO.

Sorghum seeds treated with Malathion 5% dust had significantly higher percent germination than all the other treatments (Table 3). Botanical oils treated sorghum variety (Muyra-2) seeds showed none significant different in germination over the acetone treated control except at treatments with 1 ml CPO and 0.75 and 1 ml NSO. The treatments with botanical oils reduced germination of sorghum seeds compared to treatment with Malathion 5% dust. The study indicated that NSO and CPO could affect the seed germination of stored sorghum. The reduction in seed germination could be because of molds development on the treated seeds as the oils increased the moisture content of seeds. Similarly, Abrham and Basedow (2005) reported that NSO extracts reduced sorghum seed germination more significantly than the untreated check. Singh *et al*. (2012) reported that, oil can have an adverse effect on the germination power of treated seeds. Also, Ajayi *et al*. (2014) reported that the essential oil monoterpenes components, carvacrol, 1-8-cineole and eugenol treated at 10 and 20 µl/L on stored cowpea for the control of storage pest affects seed germination and seedling growth compared to the control. It also negatively affected shoot length and number of seedling leaves and reduces plant growth. Therefore, it is recommended that seed which is intended for sowing should not be treated with the oils. In the case of lower rates of botanical oil extracts and acetone treated control, the percentage seed germination was lower due to serious damage of the sorghum seed by the maize weevil and mold development on the surface of the germinating seeds. Sergio. (1978) reported that many of the important pests which attack cereals and legumes greatly affect the seed germination capacity when the insect population becomes higher.

Simple Correlation Coefficient among the Variables

The simple linear correlation is presented in (Table 4). Adult maize weevil mortality was positively correlated with the variables of Percentage seed protection (r = 0.97) and seed germination (r = 0.62). However, adult maize weevil mortality was negatively correlated with F_1 progeny emergence (r = -85), seed weight loss (r = -98) and damage (0.62). F_1 progeny emergence was positively correlated with seed weight loss (r = 0.86) and damage (r = 0.90) and negatively correlated with the percent protection (r = -0.87) and seed germination (r = -0. 55). Percentage protection was positively correlated with seed germination (r = 0.63)

Table 3 Effect of NSO and CPO on weight loss, damage and germination

Treatment	Rate(ml or g/0.1kg)	Weight loss %	Damage %	Germination %
CPO	1.50 ml	0.3^{f}	1.1^{f}	70.3^{bc}
	1.00 ml	1.6^{e}	4.7^{e}	73.3^{b}
	0.75 ml	1.9^{e}	5.6^{e}	62.5^{bc}
	0.50 ml	3.1	8.5^{d}	64.8^{bc}
	0.25 ml	5.9^{c}	14.6^{c}	65.8^{bc}
NSO	1.50 ml	0.0^{f}	0.0^{g}	59.8^{bc}
	1.00 ml	0.0^{f}	0.0^{g}	73.8^{b}
	0.75 ml	0.3^{f}	0.9^{f}	77.0^{b}
	0.50 ml	7.6^{b}	20.6^{b}	55.8^{bc}
	0.25 ml	9.6^{a}	25.5^{b}	56.0^{cd}
Malathion5% dust	0.05 g	0.0^{f}	0.0^{g}	92.3^{a}
Acetone treated	2.00 ml	10.7^{a}	31.9^{a}	47.8^{c}
CV	5.22	10.4	8.6	
SE	0.01	2.10	22.8	

Means in columns with same letter are not significantly different at α = 0.01. Mean separation was analyzed by SNKT

Table 4 Correlation coefficient of *S. zeamais* infestation on botanical oil treatment

Variables	AWM (%)	F_1	PP (%)	WT %	GD%	GP%
AWM (%)	1					
F_1	-0.85**	1				
% protection	0.97**	-0.87**	1			
WT %	-0.98**	0.86**	-0.97**	1		
GD%	-0.97**	0.90**	-0.98**	0.98**	1	
GP%	0.62**	-0.55**	0.63**	-0.62**	-0.64**	1

AWM, Adult weevil mortality; F_1, progeny emergence; PP, Percentage protection; WT, weight loss; GD, Seed damage; GD, Seed Germination; all values highly significant at α = 0.01.

and negatively correlated with seed weight loss (*r* = -0.97) and damage (*r* = 0 .98). Weight loss was positively correlated with seed damage (*r* = 0.98) and negatively correlated with seed germination (*r* = -0.62). Seed damage was negatively correlated with seed germination at (*r* = -0.64).

SUMMARY AND CONCULSIONS

A study on the post harvest management of the maize weevils, *S. zeamais* was conducted under controlled condition in Plant Protection Laboratory at Haramaya University in 2015. The treatments were arranged in CRD with four replications. The objectives of the study were to determine the effective doses of neem seed and citrus peel oil extracts against *S. zeamais* and to evaluate some improved sorghum varieties and landraces for resistance to the *S. Zeamais.*

The NSO and CPO treatments resulted in high adult weevil mortality and seed protection from F_1 progeny emergence. F_1 progeny emergence, seed weight loss and damage were significantly reduced compared with the acetone treated control. NSO and CPO treatments resulted in high adult weevil mortality and seed protection from F_1 progeny emergence. Higher parent adult weevil mortality was obtained with CPO on 14 to 28 days after treatment application. NSO treatments resulted higher weevil mortality on 7 to 28 days after treatment application. The higher rates of NSO and CPO at 1, 1.5 and 0.75 ml NSO resulted in greater than 90% adult weevil mortality 28 days after treatment. Generally, the potency of CPO and NSO increased with increased dose and exposure time.

F_1 progeny emergence was zero when 0.1 kg sorghum seeds treated with 1 and 1.5 ml NSO. Lower number of F_1 progeny weevils of 20.5 and 27 emerged on sorghum seeds treated with 1.5 ml CPO and 0.75ml NSO, respectively. The lower rates of NSO and CPO showed higher number of F_1 progeny emergence. The higher rate of NSO at 0.75, 1 and 1.5 ml and CPO at 1 and 1.5 ml showed greater than 90% sorghum seed protection from maize weevil infestation. Generally this result showed that as the amount of NSO and CPO increased F_1 progeny emergence decrease and percentage seed protection increased.

All NSO and CPO rates, except NSO at 0.25 ml showed significant different over the acetone treated control, in reducing seed weight loss. Seed weight loss due to the higher rate 0.75, 1 and 1.5 ml NSO and 1.5 ml CPO had lowered similar with Malathion 5% dust. In the case of seed damage, all the treatments were significantly different from the acetone treated control. Similar to the weight loss due to NSO from 0.75 ml and above and CPO at 1.5 ml showed comparable result with Malathion 5% dust in preventing seed damage. The result indicated that within 70 days of storage, percentage weight loss and damaged seed decreased with the increases on the rates of both NSO and CPO. The botanical treatments showed reduced percentage germination even on the fully protected sorghum seeds compared to Malathion 5% dust. Germination percentage was reduced on as the dose of NSO and CPO increased and indicates that NSO and CPO could affect the germination of sorghum seeds.

Therefore, it can be concluded that, the efficacy of NSO and CPO against *S. zeamais* increases with increase in the dose of botanical oils. NSO at 1 ml and CPO at 1.5 ml per 0.1 kg of sorghum seed were required for effective management of *S. zeamais* in storage for 70 days. As NSP and CPO affected germination sorghum seeds, it is recommended that seed which is intended for sowing should not be treated with botanical oils. Under small holder farmers' condition, however, both the NSO and CPO can be preferably used to protect their seeds from *S. zeamais* damage and safely stored for consumption as there is no report on side effect of the botanical oils on human health.

Acknowledgement:
The completion of this study would have not been realized without the help of others and I would like to take this opportunity to thank everyone who helped me with this study. First I would like to express my thanks and appreciation to Mulatu wakgari (PhD), Mr. Muluken Goftishu, Mashila Dejjene (PhD),Tesfay Belay (PhD) and Firdu Azerefegn(PhD) for their critical review of the paper. It has helped me to improve the quality of the report and compilation of my work. The research work reported in this paper in collaboration with my home institution Tigray Agricultural research Institute, Mekelle Agricultural research Center. I am very grateful to, Tigray Agricultural Research Institute for the financial support and Haramaya University for free laboratory material support.

Conflicts of interest: The authors stated that no conflicts of interest.

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