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Effect of Selected Botanicals and Local Seed Storage Practices on Maize Insect Pests and Health of Maize Seeds in Jimma Zone

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ABSTRACT
An experiment was conducted in 2011 to assess key insect pests associated with stored maize, the damage and loss they cause, efficacy of selected botanicals on the key insect pest (weevil) and the health of maize seeds. More than 50 representative farm stores were assessed in Jimma zone of Oromia National State to collect maize seeds. From the survey, seventeen arthropods (thirteen from Coleopteran, three from Lepidoptera and one from Acarina) were documented. Among all pests the challenge caused by a cosmopolitan storage insect pest, the maize weevil (*Sitophilus zeamais* Motschulsky) was economically very important. Despite differences in storage practices (indoor and outdoor storages) and the use of different containers for seed storage, the insect pest "Weevil" heavily infested seeds stored under both major storage practices. Also none of the storage practices and containers used by the farmers prevents weevil infestation. Maximum numbers (mean of 70.45) of maize weevils per 100 g of maize seeds were recorded followed by grain moth (11.26) and rice weevil (9.06). Quantitative weight losses ranging from 35.33-91.67% were common and the rate of loss reaches its maximum within six months (80.16% on average) after initial storage. This devastating damage and loss, mainly caused by weevils, prompted to screen some locally available botanicals known to have potential insecticidal properties. The results of the efficacy study showed that the three plant products (*Chenopodium* sp. whole plant powder, *Nicotiana* sp. leaf powder and *Maesa lanceolata* leaf powder) of screened botanicals have high efficacy in controlling weevil by causing adult weevil mortality (22.22-66.67%) and reducing emergence of new progeny from 80% to 28% (*Chenopodium*), 36% (*Nicotiana*) and 40% (*M. lanceolata*). It is recommended that integrated method of weevil management should receive high priority to prevent damage and losses incurred. The management practices should focus on further developing these botanicals and integrating weevil tolerant traits in maize breeding. There is strong need for training of farmers in all aspects of insect pest management.

Key words: Botanicals, integrated pest management, maize seeds, maize seed damage, loss, *Sitophilus zeamais*, storage insect pests

INTRODUCTION
Maize (*Zea mays* L.) is an important cereal crops in the world's agriculture. It is a high yielding, adaptable to wider agro-ecologies, cosmopolitan crop for which it is often named as "Queen of cereals". The grain is rich in carbohydrate, protein, oil and crude fiber. FAOSTAT (2014) reported over two million hectares (2,013,045 ha) of land were cultivated for maize in Ethiopia. From these hectares of land harvested approximately 6.2 million tonnes maize was produced in 2012 production season. The average productivity of maize in the world is 4.33 t ha^{-1}, whereas it is less than 3 t ha^{-1} in Ethiopia. In Ethiopia in general and Jimma area in particular, maize is one of the major cereal

crop grown for its food, feed, firewood and construction values. It is one of the most important staple food and cash crop providing calories for the consumers and income for the producers. Traditionally maize grain is stored by Ethiopian farmers to use and sale it in the later months of the year depending on the quantity produced per household when market price is assumed to be better.

The production and productivity of maize in Ethiopia has been increased since the development of high yielding hybrid maize variety by Ethiopian Institute of Agricultural Research (Bako Agricultural Research Center). In Jimma area, maize is a dominant cereal crop since the release of hybrid maize varieties such as BH-660. Large areas of the zone are covered by maize crop and still the area under production is increasing from time to time if not because of seed constraint and insect pests damage. The hybrid varieties were reported to be not tolerant and or resistant to insect pest attack both in the field and storage (Demissie *et al.*, 2008). Hence, farmers were not as such the beneficiary of this boosted production and productivity from the new varieties. Naturally the crop is attacked by several pests (insect and non-insect) in the field and in storage (Tadesse, 1995; Demissie *et al.*, 2008).

Among the major constraints of maize production and productivity in tropical countries including Ethiopia are the damage caused by insect pests both in the field and storage. The most important insect pests that cause damage to maize are stalk borers (in the field) and weevils (in storage) (Emana and Tsedeke, 1999). Research findings indicate that more than 37 species of arthropod pests are associated with maize grain in storage (Tadese, 1997). Most of the maize grain harvested is either stored on the farm where postharvest pests' management practices are inadequate (Dubale, 2011) or sold at throw away price far less than the production cost. Both decisions are losses to the farmers and such losses after harvest in storage is comparable with a loss of cash from pocket and therefore intolerable.

Globally losses of grain and pulse crops after harvest is estimated to be 10% and this is mainly by insect pests and it is very serious in developing country (Boxall *et al.*, 2002). FAO (1985) estimated that storage pests and lack of proper storage methods destroy 200 million tons of grains each year. The grain loss in Ethiopia ranges from 2-30% (Firdissa, 1999). In most cases, management of stored product pests depends on synthetic insecticides which have multidimensional disadvantages. This necessitated the search for more eco-friendly alternative insect pest management options such as the use of plant products. Many researchers have tested different plants and their parts against some of the most important stored product pests such as weevils and moths (Jembere *et al.*, 1995; Bekele *et al.*, 1997; Mekuria, 1995; Adane and Abraham, 1996; Bayeh and Tadesse, 1996; Firdissa and Abraham, 1998; Emana, 1999).

Information on stored products, pests of maize and their management in Jimma zone of Oromia regional state-Ethiopia is meager. Thus, this experiment was carried out to assess the major insect pests associated with stored maize, the damage and loss caused by the insect pests, efficacy of selected locally available botanicals on weevil under laboratory condition.

MATERIALS AND METHODS

Description of the study areas: Survey was conducted to collect maize grains from different Woredas of Jimma Zone for the study. The survey was conducted in Oromyia Regional State, in major maize growing areas (Yebu, Asendabo, Seka, Dedo and Kersa) of Jimma zone. The areas are found in mid to high altitudinal ranges with warm and humid climate. Laboratory studies were conducted at Jimma University, College of Agriculture and Veterinary Medicine (JUCAVM), Entomology Laboratory. JUCAVM is located 350 km south west of Addis Abeba, the capital city of Ethiopia.

Sample collection procedures: The studies were conducted in Jimma zone of Oromiya Regional State, southwest Ethiopia. The survey areas were generally warm and humid and favorable for pest infestation in storage. The survey was conducted in 2011 when there was maize grain in storage, three to six months after storage and when infestation and grain damage levels were most likely to be prevalent. Survey sites (Woreda) were selected based on their maize production status (major maize producing areas) of the zone. A total of 50 farm stores were visited and composite samples were collected from these stores for laboratory studies. Selection of sites, storage containers and samples were made in such a way that they are the representative of the woreda at random. When a selected site or storage did not have maize the next site or storage was taken as a substitute. From each container, three samples, each consisting of 100 g of maize grain seed, were taken. The samples were obtained from as many different parts of the various storage facilities as possible (top, sides, centre and bottom). Each sample was put in a paper bag and was labeled with the necessary information (name of the site, sample number, date of sampling, storage time, etc.). The samples obtained from the same storage were mixed together and placed in a cloth bag for further inspection in laboratory.

Laboratory study: After samples were collected each time, in laboratory, each sample of maize grain was sieved over a 2 mm mesh sieve and all fractions were examined. Insects were removed, counted and grouped according to order or genus and were preserved dry as pinned collections or in 75% alcohol for identification using available literature. In the laboratory, at JUCAVM, associated insect pests with maize seed were separated, their abundance and identity were established using available literature and facilities. Sampled grains were separated into damaged and undamaged, weighed, numbers counted and percentage weight loss was determined using the equation developed by Adams and Schulten (1978) as indicated:

$$\text{Weight loss (\%)} = \frac{(U \times Nd) - (D \times Nu)}{U(Nd + Nu)} \times 100$$

where, U is weight of undamaged grain, Nd is number of damaged grain, D is weight of damaged grain and Nu is number of undamaged grain.

Bio assay study: Efficacy of three botanicals (*Chenopodium* sp., *Nicotiana* sp. and *Maesa lanceolata*) were assessed against *S. zeamais*. For this study weevils of known number (25 adults) were introduced into clean jar with clean maize seeds (Variety BH-660-hybrid high yielding variety). Before starting bio-assay study, weevils were sufficiently reared on BH-660 maize variety under laboratory condition at JUCAVM at room temperature. The whole plant of *Chenopodium* sp., leaf of both *Nicotiana* sp. and *Maesa lanceolata* were collected from the field, shade dried and made into powder using mortar and pestle. These botanicals, insecticidal properties were compared with two controls: Standard check (Actellic dust) and control (no treatment) making up the total number of treatments five. These treatments were arranged using completely randomized design and replicated three times.

Hundred gram of clean maize seeds were weighed and added into clean jars. The botanicals powder was each applied at 10 g into the respective jars. All the jars were infested with 25 adult maize weevils screwed well and left in the laboratory for one to six months. After a month, adult mortality percentage was assessed by using Henderson and Tilton (1955) equation based on the average number of dead insects in each treatment as stated:

$$\text{Corrected mortality (\%)} = \left(1-\frac{\text{n in Co before treatment}\times\text{n in T after treatment}}{\text{n in Co after treatment}\times\text{n in T before treatment}}\right)\times 100$$

where, n is insect population, T is treated and Co is control.

The stored grains were maintained for 2, 4 and 6 months to study the effect of the weevils on grain damage and for two months to study the effect of botanicals on eggs hatching percentage. All data were statistically analyzed using SAS (2008) 9.2 version and when found significant at 5% level of significance, means separation was made using Least Significant Difference test.

RESULTS AND DISCUSSION

Insect pests recorded and their pest status: Lists of the major insect pests and their pest status are indicated in Table 1 and 2. Seventeen arthropods were recorded on maize grain in Jimma zone. Twelve species of Coleoptera in six families, four species of *Lepidoptera* in two families and one species of *Acarina* were identified and considered to be damaging maize grain in storage. Among the different arthropods, the dominant species in all areas surveyed were maize weevil, *Sitophilus zeamais* followed by Angoumois grain moth; *Sitotroga cereallela*; rice weevil, *S. oryzae* and flour beetle, *Tribolium confusum* (Table 2). These insect pests were widespread, abundant and caused damage and loss to maize grain. Tadese (1997) collected 37 species of arthropods associated

Table 1: Taxonomic positions of insect pests associated with stored maize and their status in Jimma zone of Oromia regional state, Ethiopia (2011)

Orders and families	Common names	Scientific names	Status of the pest
Coleoptera			
Curculionidae	Rice weevils	*Sitophilus oryzae* (L.)	Major
Curculionidae	Maize weevil	*S. zeamais* Motschulsky	Major
Cucujidae	Flat grain beetle	*Cryptolestes pusillus* (Schonherr)	Intermediate
Cucujidae	Red rust grain beetle	*Cryptolestes ferrugineus* (Stephens)	Minor
Bostrichidae	Lesser Grain Borer	*Rhyzopertha dominica* (Fabricius)	Intermediate
Bostrichidae	Larger grain borer	*Prostephanus truncates* (Horn)	Minor
Tenebrionidae	Flour beetle	*Tribolium* sp.	Intermediate
Tenebrionidae	Red rust flour beetle	*T. castaneum* (Herbst)	Intermediate
Tenebrionidae	Confused flour beetle	*T. confusum* Jacquelin du Val	Major
Tenebrionidae	Yellow mealworm beetle	*Tenebrio molitor* L.	Minor
Buruchidae	Mexican bean weevil	*Zabrotes subfaciatus* (Boheman)	Intermediate
Silvanidae	Saw toothed grain beetle	*Oryzaephilus surinamensis* (L.)	Minor
Lepidoptera			
Pyralidae	Tropical warehouse moth	*Ephestia cautella* (Walker)	Intermediate
Pyralidae	Rice moth	*Corcra cephalonica* (Stainton)	Intermediate
Pyralidae	Indian meal moth	*Plodia interpunctella* (Hubner)	Intermediate
Gelechiidae	Angoumois Grain moth	*Sitotroga cerealella* (Olivier)	Major
Acarina			
Acaridae	Flour mite	*Acarus siro*	Minor

Table 2: Mean number of the most important insect pests of maize recorded from maize grain samples in Jimma zone of Oromia regional state

Insect pests of maize		
Common name	Scientific name	Mean number per 100 g of seed (Mean±SEM*)
Rice weevil	*Sitophilus oryzae*	9.06±1.01
Maize weevil	*S. zeamais*	70.45±2.01
Flour beetle	*Tribolium* sp.	0.65±0.28
Red flour beetle	*T. castaneum*	0.38±0.45
Confused flour beetle	*T. confusum*	5.25±0.51
Mexican bean weevil	*Zabrotes subfaciatus*	0.46±0.14
Tropical warehouse moth	*Ephestia cautella*	0.66±0.23
Indian meal moth	*Plodia interpunctella*	0.80±0.15
Grain moth	*Sitotroga cerealella*	11.26±1.13

*SEM: Standard error of mean

with stored maize grain seeds in western part of Ethiopia, Bako area. He further stated the most important arthropod was maize weevil, grain moth and flour beetle in that order. However, Emana (1993) reported *S. cereallela* followed by *S. zeamais*, as the two most important pests of stored maize in southern Ethiopia. This may be because of the similarity of the physical conditions which is warm and humid both in Jimma and Bako area and differences in southern part which is cooler environment. There was no new record of arthropod associated with maize from previous workers (McFarlane, 1969; Walker and Boxall, 1974; Tadesse, 1991, 1997; Firdissa, 1999; Sori and Ayana, 2012) in this area probably because the record was made on most dominant species alone suggesting the need for further in-depth study in Jimma Zone. There were many other insect and non-insect pests and also beneficial arthropods of concern yet not recorded in the current study. Most of the insect pest species recorded was those happen to be of great challenge in stored maize damaging the seed and forcing farmers to sale their produce at very low price immediately after harvest.

In a comparative assessment of the different arthropods recorded on maize in storage, *S. zeamais* was the most common and perhaps the most destructive of all the insect pests recorded (Table 2). Most of the insects mentioned above were found attacking maize; however, *S. zeamais* was recorded from all the samples in all the sites in abundance. The grain weight loss caused by these insect pests was estimated to be 63.85% on an average within three to six months of storage. However, the weight losses vary from place to place ranging from 35.33-91.67% (Table 3). Schmutterer (1971) reported the severity of *S. zeamais* on both maize and sorghum in storage and showed a loss estimate of upto 80% in maize stored in unprotected silos in Bako area. Considering the economic importance of *S. zeamais*, efficacy of three botanicals and their impact on maize weevil was studied.

The bruchid, (*Z. subfasciatus*) was recorded for the first time in 1989 in Ethiopia from haricot bean (*Phaseolus vulgaris* L.) with which maize seeds were sparsely mixed in the Bako research center farm store. Walker and Boxall (1974) recorded the curculionid *S. zeamais* on haricot bean in Ethiopia. *Zabrotes subfasciatus* is one of the important bruchids attacking haricot beans and other pulses in Africa. Abate *et al.* (1982) did not mention the presence of this species in Ethiopia. However, during the present survey it was recorded as the only and most dominant bruchid attacking maize stored in the survey area. In general it can be said that few of the species recorded

Table 3: Mean percentage grain damage and weight losses of stored maize grain at different site (Jimma zone) 3-6 months after storage (n = 50)

		Percentage (average)	
Sites	No. of stores (n = 50)	Grain damage	Weight loss
1	4	73.67	69.33
2	2	64.33	50.67
3	3	54.33	55.33
4	4	63.44	67.33
5	4	72.80	70.67
6	2	55.33	75.67
7	2	61.33	76.67
8	2	57.40	78.33
9	4	72.11	55.33
10	3	68.33	56.67
11	3	56.00	41.67
12	2	75.77	89.33
13	4	56.30	91.67
14	2	67.50	35.33
15	1	72.90	87.67
16	1	53.67	45.33
17	2	72.77	56.00
18	3	64.20	49.67
19	1	70.13	48.67
20	1	59.67	75.67
Mean±SEM		64.60±7.28	63.85±16.19

in the present study are cosmopolitan pests in stored products. Most of the insects and non insect pests appeared to be less important, less abundant and difficult to collect were not recorded because they appear to be of no importance as important pests. Yet further investigation need to be conducted.

Grain damage and weight loss: There was a significant grain damage and weight loss caused by the pests (Table 3). Mean percentage grain damage and weight loss caused by the pests under farmers storage practices were 64.60 and 63.85%, respectively. The maximum damage and weight loss was believed to be caused by maize weevil (*S. zeamais*). This is because the mean number of maize weevils collected from 100 g of stored seeds was maximum (70.45±2.01) when compared with other insect pests (Table 2). Collectively, a comparative analysis of losses due to all the pests in storage resulted to an average loss of 63.85% of the stock after 3-6 months of storage indicating the importance of pest management in storage under Jimma condition. Grain damage ranged from 53.67-75.77% between three to six months of storage where as the weight loss varied from 35.33-91.67% (Table 3). More the number of insect pests at each site were associated with more percentage of grain damage and weight losses. The highest grain damage and weight loss at all location may be due to the conduciveness of the environmental condition for the insect pests. The storage loss was found to be 80% in Cameroon after 6-8 months of storage (Nukenine *et al.*, 2002) which is comparable with the present study.

Adult mortality: The efficacy of the botanicals on adult maize weevils is shown in Table 4. There were significant differences among the treatments on adult weevils' mortality ($p<0.05$). Among the botanicals tested, *Chenopodium* sp. whole plant powder gave maximum corrected mortality (66.67%) which is comparable and on par with the standard checks Actellic dust (70.39%). However, all the botanicals have shown some percentage of potency against maize weevil. Different workers (Ibe and Nwufo, 2001; Mbah and Okoronkwo, 2008; Okonkwo and Okoye, 1996; Asawalam *et al*., 2007) have confirmed the effectiveness of different botanicals against maize weevils. The present study is in agreement with their findings.

Progeny emergency: The effect of the different botanicals powder on the progeny emergency was indicated in Table 5. There was significant influence of botanicals on hatchability of *S. zeamais* eggs. Maximum hatching percentage was observed from the control (80%) and minimum was recorded from the actellic dust (20%) received jars followed by *Chenopodium* (28%). However, all the botanicals had insect emergency inhibition effect.

Grain damage: Percentage grain damage due to maize insect pest, *S. zeamais* under selected botanical treatments was found to be significant (Table 6). In general, it can be said that the

Table 4: Effect of plant products powder on *S. zeamais* mortality (%) a month after treatment application

Treatments	Plant parts used	Rate (g/100 g of seed)	No. of insects inoculated	Mean No. of dead insects	Mortality (%)
Chenopodium	Whole	10	25	19.00	66.67[a]
Nicotiana	Leaf	10	25	16.00	50.00[b]
M. lanceolata	Leaf	10	25	11.00	22.22[c]
Actellic dust	-	0.04	25	19.67	70.39[a]
Control	-	-	25	7.00	0.00
LSD (5%)					5.28
CV (%)					8.36

Table 5: Effect of botanicals powder on hatchability of maize weevil two months after storage of the grains at JUCAVM (2011)

Treatments	No. of eggs studied (a)	Mean No. of eggs hatched out (b)	Hatchability (%) (b/a×100)
Chenopodium	25	7	28
Nicotiana	25	9	36
M. lanceolata	25	10	40
Actellic	25	5	20
Control	25	20	80

Table 6: Effects of plant products powder on maize grain damage after 2, 4 and 6 months of storage periods

Treatments	No. of grains sampled	No. of damaged grain after month			Percentage of damaged grain after month		
		2	4	6	2	4	6
Chenopodium	250	15	30.00	72.0	6.0	12.0	28.80
Nicotiana	250	17	32.00	74.0	6.8	12.8	29.60
M. lanceolata	250	23	41.00	81.0	9.2	16.4	32.40
Actellic	250	12	25.00	45.0	4.8	10.0	18.00
Control	250	44	155.50	200.4	17.6	62.2	80.16

botanicals protected maize grain from weevil damage. *Sitophilus* weevils caused much more grain damage in the untreated control treatment. Mean percentage grain damage caused by weevils were 17.6, 62.20 and 80.16% after 2, 4 and 6 months after storage, respectively in the control treatment whereas the grain damage was 6.0, 12.0 and 28.8% in *Chenopodium* treated jars which offered the maximum protection to the grains among botanicals. Minimum grain damage was recorded from Actellic (4.8, 10 and 18% damage after 2, 4 and 6 months of storage). Reduced damage in the botanicals treated jars is the result of the efficacy of the botanicals against maize weevil infestation in storage. This is because the botanicals inhibited hatching of the eggs and less weevils were there to cause damage to the seeds or may be because of the feeding inhibition of the botanicals. This finding is consistent with the findings of Ibe and Nwufo (2001) and Dike and Mbah (1992) who have worked on different plant products to protect maize and cowpea in storage from insect pest damage.

CONCLUSION

Maize forms a major staple food and feed sources for millions of people of Ethiopia and Jimma area alike. More than seventeen important insect pests were associated with stored maize in Jimma area. Among these, maize weevil followed by grain month, rice weevils and flour beetle in that order are the most important storage insect pests limiting storability of the crop. Considerable grain damage associated with huge loss of upto 91.67% was caused by the pests within 3-6 months of storage without management practices. The fact that the use of botanicals help to improve the storability of maize with less damage from maize weevils could suggest that they can be effectively used for weevils' management. All of these plants are also easily found and can be cultivated in Jimma area that makes them affordable to resource poor farmers reducing the use of expensive synthetic chemicals with negative impacts on environment and humans.

In the present study, the importance of these pests were underlined but further study that covers all growing area to evaluate the economic importance of their infestation in the field and storage for devising bio-intensive integrated pest management strategies is needed. Nationwide surveys should be carried out to determine the species of pests associated with stored produce in Ethiopia in general and with stored maize in particular. In addition, losses caused by the major pest species in the different types of stored produce and storage structures should be determined.

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