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DEPARTMENT OF ZOOLOGICAL SCIENCE

THE STATUS OF STORED MAIZE GRAIN INSECT PESTS IN GONCHA SISO ENESIE DISTRICT, EAST GOJJAM, NORTHWEST ETHIOPIA

BY

HUNEGNAW FENTAW

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ADVISOR: EMANA GETU (PHD), PROFESSOR OF ENTOMOLOGY

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Approval sheet

As a member the Board of Examiners of the MSc thesis open defence examination, we have read and evaluated this thesis prepared by Huneghaw Fentaw entitled “The Status of Stored Maize Grain Insect Pests in Goncha Siso Enesie, East Gojam Zone, Amhara Region, Northwest Ethiopia” we hereby certify that the thesis is accepted for fulfilling of the requirements for the award of Degree of MSc in Biology.

Board of Examiners

Prof. Emana Getu ____________________ ____________

Name of Advisor Signature Date

Dr. Melaku Gima ____________________ ____________

Signature Date

Name of examiner

Dr. Bezawork Afework ____________________ ____________

Name of Chairperson Signature Date

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Abbreviations/Acronyms

CM=commodity management

D=weight of damaged grain

DA= Department of Agriculture

IPM = integrated pest management

Nd =number of damaged grain

Nu= number of undamaged grain

SM= store management

U =weight of undamaged grain

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Abstract

Maize (Zea mays L.), is an important cereal crop in Ethiopia, which is used for the purpose of food for humans and feed for animals. It is also one of the most suitable food and cereal crops supplying energy for the eaters and profit for commerce man. The study on the status of stored maize grain insect pests in Gonch Siso Enese was carried out from August 2022 to August 2023. The main objective of this study was to assess the status of stored maize grain insect pest in Goncha Siso Enesie, Amhara region, Northwest Ethiopia. A total of 130 respondents were randomly selected from 12 kebeles for data collection through questionnaire, interview and observations. Seed samples were collected from 40 storages each consisted 250g of maize grains to identify insect pests associated to maize grains and the grain damage and weight loss due to these insect pests. The seed samples were collected over three periods at two months intervals beginning after two to six months storage. Data were analyzed and interpreted by qualitative and quantitative methods. Mean grain damage and weight loss were analyzed using excel and one way ANOVA in SSPSS. All respondents use traditional maize storage methods such as Mamma, Gotera, Kot and sacks. Farmers face insect pest problems in all the storage methods. Kot in living house and mamma were more vulnerable to insect pests. Gotera was moderate and sacks with pesticides were the slightest to be infested by insect pests. The major insect pests that infested stored maize grains were maize weevil (Sitophylus zaemais Motschulsky), Angoumois grain moth (Sitotroga cerealella Olivier) and red flour beetle (Tribolium castaneum Herbst). Maize weevils (57.32%) and Angoumois grain moth (31.17%) were the most abundant primary pests, while red flour beetles (10.25%) were the least abundant and secondary insect pests. The mean maize grain damage after two, four and six month storage due to insect pests were 6.13%, 13.88% and 41.55% and mean weight losses were -11.89%, -5.57% and 5.71%, respectively . Grain damage and weight loss increased as storage periods increased. The present study indicated that farmers in the study area stored their maize in traditional storage structures that are susceptible to insect pests such as maize weevils, Angoumois grain moths and red flour beetles that caused grain damage and loss and the study recommended that need to create awareness for farmers to use improved and modern storage structures to enhance maize storage periods.

Key words: Infestation, stored grain insect pests, storage methods, maize varieties and grain damage.

1. Introduction

1.1. Background of the study

Maize (*Zea mays* L.), is an important cereal crop in Ethiopia, which is used for food for humans and feed for animals (Tolesa, 2019). It is one of the most important sources of nutrition. It is also one of the most suitable food and cereal crops supplying energy for the eaters and profit for commerce man (Shiferaw et al., 2011). Maize is grown in different regions of Ethiopia (Food and Agriculture Organization of the United Nations (FAO), 2012); Tadesse and Alemayehu, 2017). According to Amsalu Ayana (2012), the production and productivity of maize has increased since the development of high yielding hybrid varieties by the Ethiopian Institute of Agricultural Research (Bako Agricultural Research Center). Amhara region is one of the regional states of Ethiopia, where maize is commonly grown (Ethiopian Agricultural Research Institute (EARI), 2019).

Maize production in Amhara reached more than 18 million quintals in 2014/15 production season with engagement of more than 2.67 million small holder farmers (CSA, 2015). In East Gojjam zone, maize production ranks third (13.7%) in terms of area coverage (Getachew et al., 2020). Goncha Siso Enesie is one of the districts in East Gojjam zone, where its large areas are covered by maize.

Although large areas of the district are covered by maize, the benefits from maize by farmers of the district are low because of various biotic and abiotic factors. The maize is highly vulnerable to the insect pests both in the field and storage (Assefa, and Birhanu, 2016; Mulugeta and Seyoum, 2018). Farmers in Goncha Siso Enesie district produce and collect many maize grains but they do not benefit from their product because of the limitation during storage condition.

Losses resulting from poor harvest management of grains are among the key constraints for improving food and nutritional security in Africa that results in grain weight losses of 20-30% (Tefera, 2012). Farmers in Ethiopia like other African farmers, use poor traditional storage conditions that are suitable conditions for insect pests to reproduce and grow quickly in the storage. In Ethiopia, maize weevil and Angoumois grain moth are the major cause of maize grain losses (Worku et al., 2012). Likewise the lack of suitable grain storage structures and absence of storage management technologies in the tropic forced growers to sell their produce immediately after harvest (Emana, 1995). These problems are commonly seen in Goncha Siso Enesie, East

Gojjam zone. To develop best pest control methods of post harvest, identification of main insect pests and their relative abundance in relative to the storage condition is very important. In Goncha Siso Enesie, there is no scientific information on storage pests of maize which causes damage and weight losses. Therefore, the general objective of the study was to assess the status of stored maize grain insect pests in Goncha Siso Enesie, East Gojjam zone, Amhara regional state, Northwest Ethiopia.

1.2. Statement of the problem

Maize (*Zea mays* L.); is an important cereal crop in Ethiopia, which is used for food for humans and feed for animals. Goncha Siso Enesie is one of the districts in East Gojjam zone, where its large areas are covered by maize. Maize is mostly grown in Goncha Siso Enesie by local farmers. Farmers in Goncha Siso Enesie district produce and collect many maize grains, but they do not benefit from their product because of the limitation during storage condition. They use poor traditional storages and are not suitable maize grain storage structures so maize grains mostly affected by insect pests before and after harvest. In Goncha Siso Enesie, there is no scientific information on storage pests of maize which causes damage and weight losses. Hence, this study was carried out to assess the major insect pests associated with stored maize, the damage and loss caused by these insect pests in this area.

1.3. Objectives of the study

1.3.1. General objective

To assess the status of stored maize grain insect pests in Goncha Siso Enesie, Amhara region, Northwest Ethiopia.

1.3.2. Specific objectives

- To examine the species compositions, abundant and relative abundant of stored maize grain insect pests in the study area.
- To demonstrate the types of storage structure of maize in the study area.
- To assess the percent grain damage and weight loss of stored maize grain in the study area.

1.4. Research questions

This study attempts to answer the following questions:

- What is the species composition of stored maize grain insect pests in the study area?
- How abundant the stored maize grain insect pests are in the study area?
- What is the status of grain damage and weight loss of stored maize grain due to insects in the study area?

1.5. Significance of the study

The study could give current information about the status of stored maize grain insect pests in Goncha Siso Enesie district, Amhara region, Northwest Ethiopia. It is important to identify the major stored maize grain insect pests and getting such information scientifically will have a great contribution towards the protections of stored maize grain from insect pests. The study could also give awareness for farmers how to conserve and protect their maize grains from insect pests. Farmers could store their maize grains properly in good storages and get high benefits from it therefore they improve their food and nutritional security.

2. Literature Review

2.1. Origin and Importance of Maize

Maize is a cereal grain first domesticated in southern Mexico by native people about 10,000 years ago (https://en.m.wikipedia.org>wik:on 31/10/2021). Maize is an important cereal crop of the world. It is a source of nutrition as well as chemical compounds like beta carotene. It contains different types of vitamins and minerals. The vitamins that are found in maize include K, C, E, B_1 (thiamine), B_2 (niacin), B_3 (riboflavin), B_5 (pantothenic acid), and B_6 (pyridoxine). A major nutrient that is present in maize is potassium which has a good significance because an average human diet is deficient in it (Kumar and Jhariha, 2013).

About 45-50% of oil is present in maize germ and the oil is used for cooking (Orthoefer, Eastman, and List, 2003). The oils contain both saturated fatty acid (14%) and unsaturated fatty acids (86%). Maize gives for us many important health benefits. In maize, B group vitamins are essential for heart, hair, skin, and brain and good for digestion. In addition to this, the maize is important for treatment of urinary tract infection, kidney stone and fluid retention in India and china. The linolic acid in the oil of maize controls the blood pressure, the cholesterol levels in blood and cardiovascular maladies (Dupont et al., 1990; Birringer, Pfluger, Kluth, Landes, and Floe, 2002; Sen et al., 2006). Maize is also important to control chronic disease because of its phytochemical contents (Kopsel et al., 2009).

2.2. Maize Storage Conditions

Storage is a place where different grains like maize grains are stored during harvesting seasons. In agriculture storage is mainly important because the production and productivity of agriculture are needed in a particular time of the year. Therefore, there is a need to meet average demand by storing excess grains during the harvesting season for slow release to market during non harvesting seasons (Okoruwa et al., 2009). As a result, storage helps to smooth out variations in market supply both from one year to the next and from one season to the next by taking produce off the market in surplus seasons and releasing it back onto the market in lean seasons (Proctor, 1994; Komen et al., 2006; Kimenju et al., 2009). Grains are stored by farmers for their consumption and/or for seed purposes, and by traders as well as marketing agencies for financial gain in general (Chakraverty et al., 2003).

2.3. Insect Pests Associated to Stored Maize Grain

The stored maize is attacked and damaged by several pests that lead to quality weakening forcing farmers to sell at little price and under the production cost. Insect pests that affect stored maize grains are post harvest insect pests. According to Emana and Tsedeke (1999), the insect pests are generally members of two major groups such as Coleoptera (beetles) and Lipidoptera (moths). Both the larva and adults of beetles damage the stored maize and they are more diversified and highly destructive in comparison to moths, in which only the caterpillars are harmful life stages that causes damage (Upadhyay and Ahmad, 2011). According to Emana and Tsedeke (1999), the most important insect pests that cause damage to maize in the field and storage are Lepdopterous stalk borers and Coleoptrous weevils. More than 37 species of arthropod pests are associated with maize grains in storage (Abrham, 1997). Information on stored maize grain insect pest management methods, in Goncha Siso Enesie District of East Gojam Zone is not available.

2.3.1. Order Coleoptera

Sitophilus zeamais

Sitophilus zeamais is found in curculionidae family and maize weevil is its common name. It is the major pest of stored maize grain in most African countries including Ethiopia (Ahmed, 2015). Maize weevil is pest of sorghum, rice, cassava and wheat in addition to maize. Maize weevil causes substantial losses in maize. Infestation of the maize grain with maize weevil may begin when the moisture contents of the matured grain reduced. Subsequent attack with maize weevil caused by reuse of unclean storage structure that stores previously infested maize grains with maize weevil, reuse of sacks borrowed from neighbors during harvesting from fields and from the pest movement into storage when infested maize spread out near the storage. Heavy infestation may cause weight losses in stored maize.

Sitophilus oryzae

The lesser grain weevil and also named the rice weevil is pest of stored maize. It also affects sorghum, rice, wheat and cassava. It also damages barely, pearl millet, lentil, millet, broad bean, cowpea, peas and rye. The lesser grain weevil is one of the most destructive pests of grains because of its voracious feeding on whole grains (Tolesa., 2019). Its invasion may cause an increase in temperature to grains and may facilitate the establishment of fungal colonies and mites (Tolesa., 2019). In maize infestation with the lesser grain weevil starts in the matured grains when the moisture content of the grain has fallen to 18-20% (Tolesa., 2019) . Subsequent attack with lesser grain weevil caused by reuse of unclean storage structure that stores previously infested maize grains with lesser grain weevil, reuse of sacks borrowed from neighbors during harvesting from fields and from the pest movement into storage when infested maize spread out near the storage. Like maize weevil, the lesser grain weevil is found in all warm and tropical parts of the world (Tolesa., 2019). As described by Dick (1988), *S. zeamais* and *S. oryzae* are serious pests of cereals in tropics.

***Prostephanus truncates* (Horn)**

Prostephanus truncates is found in Bostrichidae family and with its common name called larger grain borer. It is pest of stored maize grains and in some areas it attacks maize grains in the fields before harvest. Infestation in maize grains may start in the field on the mature crops. Maize is its primary host. In addition to maize, larger grain borer attacks non-food substances like wood, bamboo and plastic which is difficult to control this pest. 34-40% of losses of weight recorded from maze cobs which stored for 3-6 months with 8.7 of an average loss (Hodges et al., 1983).

***Tribolium castaneum* (Herbst)**

The red flour beetle is belonging to the family Tenebrionidae in the Coleoptera order. It is pest of stored grains, flour and cereal products. The adults are reddish brown with about 4mm long and have a flattened body and distinctive antennae. These beetles have chewing mouth parts, but do not bite or sting. The red flour beetle is reddish-brown in color with three segmented club at the end of its antennae. It is similar with confused flour beetle in color but differs in its antennae.

2.3.2 Order Lepidoptera

***Sitotroga cereallela* (Olivier)**

The Angoumois grain moth is belonging to the family Gelichiidae in order Lepidoptra. It infests mainly maize although it infects barley, oats, rice, pearl millet, wheat, rye and sorghum. Angoumois grain moth found in all sub-regions of Africa and it is common in Ethiopia (Ahmed et al., 2014). It infests maize in much storage before maize weevil infestation. Subsequent infestations in storage result from the pest flying into storage facilities. The Angoumois grain moth larvae feed maize kernels. They cause grain weight and quality reduction in grains. Heavily infested grains by Angoumois grain moth smell bad odor are less attractive for consumption by the users. Presence of adult Angoumois grain moth flying nearby is an indication of infestation.

2.4. Status of Insect Pests Associated to Stored Maize Grain

Post harvest insect pests associated to grains such as maize are the first from the invasive forces to begin the interaction with the grain. According to Chakraverty et al., (2003), they are one of the major threats to the grains quality maintains during storage. Due to their ability to attack grain before harvest, feeding behavior and small size, they are the most damaging of all other pests (Talukder, 2009). According to Chimoya and Abdullahi (2011), the majority of these insect pests are cosmopolitan and polyphagous in their feeding behaviours. Stored grain insect pests damage by direct feeding on storage. They also contaminate the stored grain by excretion, molting, leaving dead bodies (Offor et al., 2014). As reported by Weaver and Petrof (2005) and Tefera et al., (2010), in most causes insects also predispose the stored grains like maize to secondary attack by disease causing pathogens such as fungi. In addition to this, according to Mason and McDonous (2012), a major concern with the presence of insects in storages is a potential to vector disease organisms because many storage insect pests have hair bodies that are suitable to carry pathogens. For example maize weevils serve as mechanical vectors for *Aspergillus niger*, *A. glaucus*, *A.candidus* and yeasts (Smalley, 1989 cited in Hagstrum et al., 2012). In general, mainly storage insect pests and to a lesser extent fungi reduce the value and quality of storage grains.

2.5. Management Options of Stored Maize Grain Insect Pests

2.5.1. Botanical control

Botanicals are the chemical that are produced by plants, and repel approaching insects, deter feeding and ovipositor on the plant or disrupt the behavior and physiology of insects in various ways (Shanker and Aprol. , 2012). These pesticide plants include spices, weeds and others (Chomchalow, 2003; Said and Pashte, 2015). Pesticide plants are used in two methods after harvest. The first method is using plant tissues directly it may be aqueous or organic solvent (Golob et al., 2002; Taluker, 2006). The second method is using active compounds which are made from plants.

Accordingly the exploitation of botanicals to guard stored commodities against insect pest attack have a very long history (Belmain and Stevenson, 2001; Isman, 2006). The utilization of local plants for stored grains protection is common in traditional storage condition in developing countries like Ethiopia (Obeng-Ofori, 2007). Accordingly botanicals are appropriate technology for resource poor small holder farmers (Isman, 2008). Botanicals have many usages more than synthetic pesticides. They are found locally and biodegradable methods (Mishra et al., 2012). They act on insect pests by direct killing, interfering with reproduction, affecting host findings and avoiding feeding (Golob et al., 2002). Their mode of action on insect pests is important to minimize loss of stored grain like maize. According to Dubey et al., (2011), botanicals cause little risk to the environment and to the human wellbeing than synthetic pesticides. In addition to this, they are not poisonous to the non target organisms (Rajashekar et al., 2012). Therefore, they keep biological diversity natural enemies, which their use a sustainable pest management in agriculture (Sola et al., 2014). The utilization of botanicals can control many pests and diseases of the world and they also minimize deforestation, desertification and erosion (Rajashekar et al., 2012).

Although botanicals are used to protect the stored grains like that of maize from insect pests, only few of them are utilized on commercial scale (Phillips and Throne, 2010; Sola et al., 2014). Example of botanicals that are traded globally include neem products from *Azadirachta indica*, pyrethrum from *Tnacetum cineraruiifolium* and rotenone from Derris and onchocarpus species (Phillips and Throne, 2010; Sola et al., 2014). However, to acquire good class commercial insecticides, farmers face shortage of financial income to protect stored grains like maize.

2.5.2. Chemical control

Fumigation and contact insecticides are the two main chemical approaches that are used for controlling insect pests of stored grains such as maize (Kostyukousky et al., 2016). Fumigation is one of the most efficient control approaches in which insect pests are exposed to a toxic gaseous atmosphere by applying a grain fumigant. They are chemicals existing in solid, gas and liquid state. In stored grains like maize they are applied on insect pests in gaseous state (Chakraverty et al., 2003). According to UPadhyay and Ahmed (2011), fumigation is applied in buildings, warehouses, small bags, soil, seed and stored products, and fume generated by fumigation enter the body of insects through the spiracle and spread to trachea and tracheoles and bind to the hemolymph components. Fumigation is utilized in stored grains to prevent the grains from insect pests developing outside and inside of the grains (Chakraverty et al., 2003). Methyl bromide and phosphine are fumigants and now a day they are utilized over the globe to preserve stored grains (Boyer et al., 2012). However, because of its effect of ozone depletion methyl bromide was phased out in developed countries and phosphine is used instead (Daglish et al., 2014). Therefore, phosphine is widely used in the world because it has easy application and low cost.

Contact insecticides are synthetics which are solids or liquids which affect insect pests when they contact with insects (Golob et al., 2002). Dust, baits, granules, soluble and wet table powders are solids. Emulsifiable concentrate, fumigants, oils, aerosols, solution and ultra-low volume are liquids (Semple et al., 1992). They are important to preserve stored grains such as maize. Accordingly insecticides kill previously existing insects and prevent cross-infestation and re-infestation of non-infested grains (Chakraverty et al., 2003).

Synthetic organic chemicals that are at this time accepted for use in stored grains insect pests management fall into one of three groups such as organophosphates, carbonates and synthetic pyrethroids (Golob et al.,2002). Organophosphates include dichloruos, malathion, fenitrothion and primiphos methyl. Carbonates include carbarykl, primicarb, alanycarb, indoxacarb and furathiocarb where as synthetic pyrethroids include biores-methrin, perimithrin, deltmethrin and phenothrin (Sample et al., 2002). Accordingly these insecticides used in management of stored grains as grain admixture treatments, residual surface, and surface treatment (Proctor, 1994; Golob et al., 2002). According to Emana (1999), synthetic pesticides are the most efficient and effective methods for protection of stored products in Ethiopia and in another place. But synthetic pesticides have negative impacts. For example, they cause poisonous to the non target organisms, the presence of toxicity in food products and pesticide resistant development by target species (Guedes et al., 1996; Subramanyam and Hastrum, 1996; Harish et al., 2013).

2.5.3. Integrated Pest Management (IPM)

Integrated pest management is a pest control approach in which all appropriate methods and techniques are used to reduce pests of grains that cause economic damage (Golob et al.,2002; Capinera, 2008). In IPM system, chemical control methods used only when other non chemical methods are insufficient to protect stored grains like maize from insect pests (Stejskal, 2003; Savoldelli and Trematerr, 2011). Good store management (SM) and good commodity management (CM) are the main fundamentals of IPM in grain storage. SM includes the climatic control in which the grain to be dry and cool when it is stored (Semple et al., 1992).

Cm reduces level of initial infestation of stored grains with insect pests. However, infestation happens by storage insect pests in tropical countries including Ethiopia in the field before harvest. Therefore, according to Sample et al (1992), the common alternatives are to treat the grain at intake with appropriate insecticides or to disinfest the loaded grains by in store fumigation. But, IPM reduces usage of synthetic insecticides, avoids pesticide resistance insect pests that damage the users and the surrounding environment (Golob et al., 2002).

In Ethiopia, synthetic pesticides are expensive and cause risks for farmers and the grain users. Thus IPM has advantages over synthetic pesticides. Therefore, the acceptance of IPM has been developing and it is being an important method (Capinera, 2008). In addition to this, it is the best alternative for the future, as it guarantees yields, reduces price, is environmentally pleasant and contributes to the sustainability of crop growing (Dent,2000).

IPM is applied in some parts of Ethiopia. The integrated use of botanical triplex, chenopodium plant powder and silicosec reduced grain loss at Bako (Demissie, 2006). In addition, maize grains are controlled from maize weevil by combining neem seed and Mexican tea powder (Ibrahim, 2017). Similarly, using combination of different botanicals protects grains that are stored from insect pests for a long period rather than using a single botanical (Dobie, 1977).

Consequently, although IPM has been well developed method for the protection of crops before gather, it has been much less well developed for the safeguard of stored grains (Golob et al., 2002). Therefore, according to Dick (1988), the development and implementation of IPM strategies for insect pests of maize in traditional small-farmers storage in Africa, including Ethiopia requires a major research and extension effort by national and international agencies as well as researches.

3. Materials and Methods

3.1. Descriptions of the Study Areas

The study area, Goncha Siso Enese District is found in East Gojjam zone. Gindewoyn is the capital town of Goncha Siso Enese District. It is 165 Km far away from Bahr Dar which is the capital city of Amhara regional state and 380 Km far from Addis Ababa, the capital city of Ethiopia (Zeleke et al., 2016) with a latitude of 11°09’60.00N and longitude of 38°00’0.E (Figure. 1). The altitude ranges between 2300-2500m above sea level. Goncha Siso Enese is bordered on the south by Enarj Enawga, on the west by Hulet Eju Enese, on the north by Abay River which separates it from the Debub Gondar Zone, and on the east by Enebse Sar Midir. It has a total of 41 rural kebeles with a total population of 165,218 (Berhan*et al*., 2011; Asmare *et al*., 2017). From these kebeles, 6 kebeles were in highland, 11kebeles in kola and 24 kebeles in woyna dega.

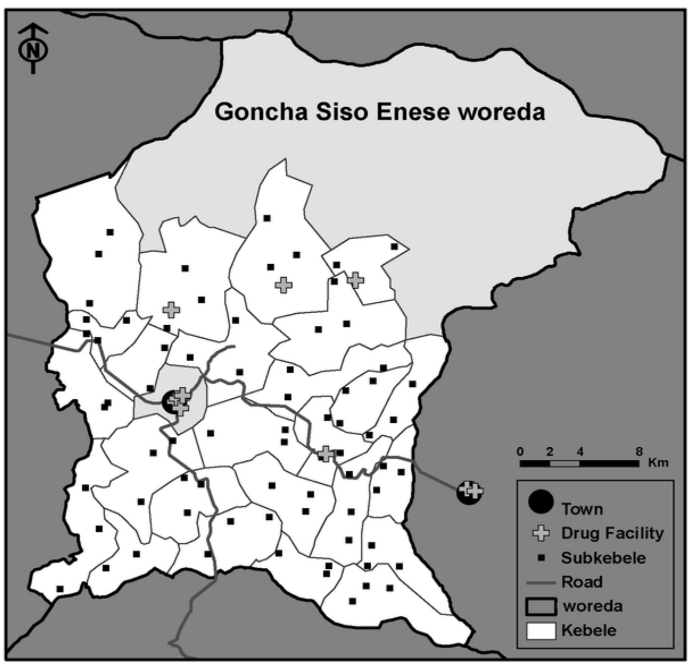

Figure 1. Map of the study area (source & credit: Berhan et al., 2011)

3.2. Materials and Chemicals

The following materials and chemical were used to collect the pertinent data:

Materials: Mish sieve (diameter of 2mm), Polyethylene bag, cloth bag, hand lens and dissecting microscopes, sampling spear and sampling scoop were the materials that were used in the study.

Chemicals: Alcohol (70%) was used to kill the insect pests.

3.2.1. The Survey

At the time of the survey, information about the physical features and location of the study area were observed. Potential maize production villages were assessed with the help of experts' from *Department* of *Agriculture* and Rural Development office of the district. Sample unit/ households were selected at the last week of November 2022.

3.2.2. Study Design and Sample Collection Procedure

The survey was conducted after maize grain stored for two to six months following Waktole and Amsalu (2012). This period was considered as the most likely occurring of infestation and grain damage levels to be serious.

Survey sites (villages) were selected purposely based on their potential of maize producing areas of the District. The representative farm stores or types of storage methods were considered from all possible maize producing kebeles. Purposively 12 kebeles of the District were selected namely,Abarwuha,Deritmaryom,Nebazla,Enezeba,Bahregiorgis,Enegodie,Laymikael,Geteseman iWafa,Yebuchr-Yewuya, Yekura- Arasma,Angot and Gosheradukat. From each kebele, sampling units, ten farmers were randomly selected following Birhanu and Emana (2018) and ten agricultural experts also were interviewed. For sample collection only 40 storages were selected randomly out of the 120 respondent farmers.

During the data collection, the volunteer farmers' household was considered. During Seed sampling, each consisting of 250g of maize grain was collected from every storage. At time of sampling, data on age of seed (how long it was stored after harvest), storage structure used, and approximate quantity of stored seed, whether maize was treated with a pesticide or not and the type of pesticide used, grain moisture content, and maize variety were recorded with the help of the district's DA and the farmers (Karta et al., 2019**).**

The grain samples were taken from three different parts of the storage facilities as possible (bottom, middle and top) using different sampling tools (such as; sampling spear, sampling scoop and human hands) following the methods used Birhanu and Emana, (2018).

The samples that were taken from the same storage were mixed together and were placed in a properly labeled cloth bag. Then the samples were taken for further examination following Firidissa (1999) method.

3.2.3. Identification of Major Insect pests

About 100g of sample was taken from each 250g of samples of the storages in order to insect pest identification. The grains were sieved using 2 mm mesh sieve in order to remove dead and alive insect pests from the sample taken following Abraham (1995**).**

Then insects (either dead or alive) were removed from each sample were counted and preserved using dry as pinned collections or in a small container having 70% ethanol for identification. The collected insects were identified through their morphological characteristics using a dissecting microscope following the procedure described by Borror et al. (2005) and Waktole and Amsalu (2012).

3.2.4. Examinations of Insect damage and not damaged grain.

From each sample, 100 maize grains were taken from each storage type and the number of insect damaged and un-damaged grains was observed using a hand lens for the presence or absence of hole or burrow following Waktole and Amsalu (2012). Then the percentage of insect damaged maize was calculated following Fekadu *et al*., (2000) and Wambugu *et al*., (2009) as follows.

$$\text{Insect damaged grain (\%)} = \frac{\text{Number of insect damaged grain}}{\text{Total number of grain}} x\ 100$$

3.2.5. Assessment of Weight Losses, Abundance, Relative abundance and Frequency of Species:

The Percentage of weight losses of maize grains due to insect pests were determined using a weight lose method and gravimetric or count method (Gebre-Selase and Emana, 2009; Zewde and Jembere, 2010). From each sample, 100 grains were taken from each storage type and the number of insect damaged and un-damaged grains was observed using a hand lens for the presence or absence of hole or burrow. Then the weight of damaged and undamaged grains was weighted with the help of triple beam balance and weight loss was calculated as follow.

$$\%\, weightloss = \frac{\text{UNd} - \text{DNu}}{\text{U (Nd} + \text{Nu)}} x\ 100$$

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.

The abundance of insect pest species, relative abundance and frequency of species found in samples were done following Bueno (1991).

Abundance can be expressed by the following formula:

$$\mathrm{Abundanceofspecies} = \frac{\mathrm{Totalnumberofindividualsofspecies}}{\mathrm{Totalnumberofsamples}}$$

The relative abundance of insect pest species was expressed by the following formula:

$$\mathrm{RelativeAbundanceofspecies} = \frac{\mathrm{numberofindividualsof\ aspecies}}{\mathrm{Totalnumberofobservedindivduals}}\mathrm{x100}$$

Constance (frequency) of insect pest species was expresses the following:

$$Frequencyofspecies\ = \frac{numberof\ samples\ in\ which\ the\ species\ occured}{Totalnumberofsamples}x100$$

3.3. Data Analysis

Data were organized in to table and then analyzed and interpreted by qualitative (descriptive method) and quantitative (percentage, frequency) methods. Mean grain damage and weight loss were analyzed using excel and one way ANOVA in SSPSS. The results were expressed using tables and figures. The insect pests were examined with the help of images from related sources and the results were discussed.

4. Results

4.1. Background of the respondents

Sex, age, education level and farming experience are shown in Table 1.Out of 130 respondents, 83.08% were males who were participating more in farming activities and 16.92% were females who are participating less in farming. Farmers with age of 51-60 were more participant (36.92%) than the other age groups during survey. Fewer youth participated in the farm. Moreover, about 35.38% of the farmers did not attend formal education and 43.07% of them attended primary education and in lesser extent 8.46% and 3.84% attended secondary and preparatory education respectively. About 9.23% of the respondents also were diploma/degree holders. The majority of the respondents had home (79.23%) which was important for co-operative working in farming works and the social problems that hinders good quality work like divorce and widow are very low and this showed as there was good working environment in the District. This outcome was similar with Emana et al. (2008) as he reported farmer's back ground determines how effective they are in producing crops. The majority of the respondents have more farming experience (45.38%) and they were elders based on the data that were gathered.

Table 1: Background of the respondents

Demographic characteristics		Frequency(n=130)	Percentage
Sex	Male	108	83.08
	Female	22	16.92
	Total	130	100
Age	18-20	3	2.3
	21-30	12	9.23
	31-40	18	13.84
	41-50	22	16.92
	51-60	48	36.92
	≥60	27	20.76
	Total	130	100

Education level	Non	46	35.38
	Primary	56	43.07
	Secondary	11	8.46
	Preparatory	5	3.84
	Diploma/degree	12	9.23
	Total	130	100
Marital status	Single	13	10
	Married	103	79.23
	Divorce	7	5.38
	Widow	7	5.38
Experience	2-4	3	2.3
	5-10	8	6.15
	11-20	27	20.76
	21-30	33	25.38
	Above 30	59	45.38
	Total	130	100

4.2. Varieties of maize cultivated in Goncha Siso Enesie

Table 2 showed the varieties of maize cultivated in Goncha Siso Enesie. Based on the data which were gathered from local respondents, farmers have not cultivated only traditional variety of maize, but they also cultivated hybrid varieties (8.33%). The majority of the farmers cultivated hybrid maize variety only. The two hybrid varieties of maize that were cultivated in the study area were BH661 and BH540. BH661was cultivated more (66.67%) by local farmers of the District than BH540 (33.33%).

Table 2: Variety of maize cultivated by local farmers in Goncha Siso Enesie based on survey data

Variety of maize		Frequency(n=120)	Percent
Traditional		10(with hybrid)	8.33
Hybrid	BH540	40	33.33
	BH661	80	66.67

4.3. Types of maize storage structures in Goncha Siso Enesie

Table 3 showed types of maize storage structures in the study area. Farmers in Goncha Siso Enesie used different types of storage for maize based on environmental condition. These include mamma (loft), gotera, kot and sacks. Farmers built mamma (loft) (Figure 3) around the living house and they used it as permanent storage for unshelled cobs (cobs with husk cover). Mamma was built from four up to eight crotches at the ground and the loft was made on crotches which are used to store unshelled cobs with husk cover. Then once it was made it can be used 3-10 years based on the raw materials used to make it.35.83% of them used it to store maize because they believed the husk is important to protect the grains from insect infestation and it decreases work loud during harvesting seasons. Other respondents stored their maize in gotera outdoor (23.33%) and kot in door (22.5%) respectively and some of them stored in sacks (18.33%). Gotera (Figure 5) was made in different structures by farmers of the study area. Some farmers made it in cylindrical form and others made it in rectangular forms. It may has roof or roofless. The roof can be made from grass or corrugated iron. Kot (Figure 4) was made inside the living house. All the above storage structures were traditional. Sacks considered as modern storage structures.

Table 3: Types of maize storage in the study area (from farmer's questionnaire)

Types of storages	Frequency (n=120)	Percent
Mamma(loft)	43	35.83
Gotera	28	23.33
Kot	27	22.5
Sack	22	18.33

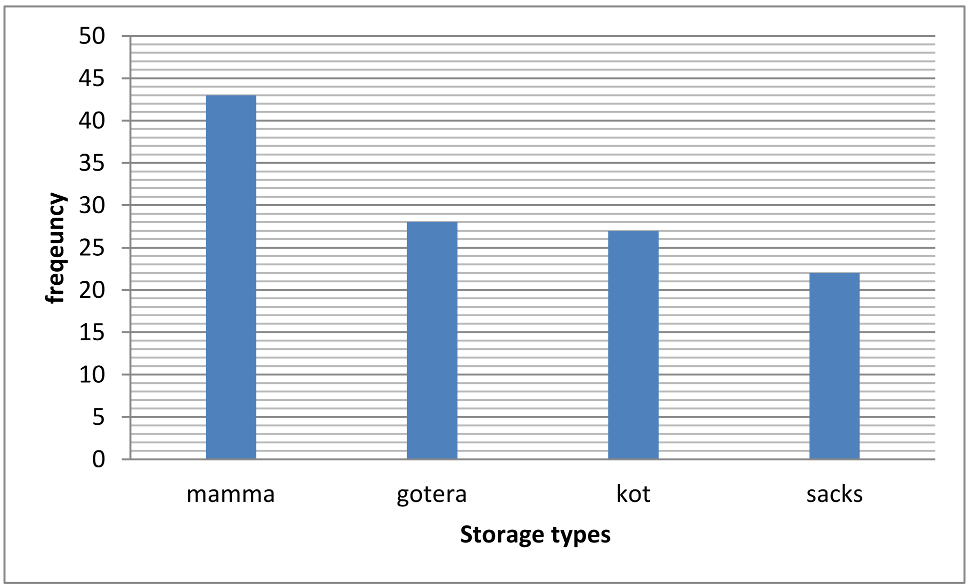

Figure 2. Storage types

4.4. Advantages and Disadvantages of Traditional Storages

Traditional maize storages have their advantages and disadvantages.

4.4.1. Mamma

It can be made from locally accessible materials and used to store unshelled maize cobs (Figure 3) and easily made so minimize work load for farmers but it has its own limitations. It cannot be used to store shelled cobs (without husk cover). It hasn't hat to protect sun light and rain so susceptible to other pests such as birds and worms in addition to high levels infestations by maize weevil and Angoumois grain moth. All mammas were infested by insect pests and the cobs were full of insect pests.

Figure 3. Mamma (unshelled cobs)

4.4.2. Kot in living house

Its advantages were for avoiding theft, birds, monkeys and apes. Some farmers preferred kot (22.5%) for storing the maize to guard it from pests such as monkeys and apes (from questionnaire) but as they respond it was vulnerable for rats in addition to insect pests.

Figure 4. Kot inside house (shelled cobs)

4.4.3. Gotera

Gotera was one of the traditional storage methods in study area. It was used to store both shelled and unshelled cobs and was made in locally available materials so it was inexpensive. It may have roof or roofless. The roof protects rain and sunlight and is used for 2-4 years of harvesting season and if it unclean it transmits insect pests from one harvesting season into the next.

Figure 5. Types of Gotera

4.4.4. Sacks

The sacks were the storage structure for maize. It was made in different sizes and may contain 50kg or 100kg. Sacks are used to carry or store maize grains. Quintal, madaberia and jute bags were sacks that used by local farmers for storage and they made from plastics.

Figure 6. Sacks storages

4.5. Form and Place of Maize Storage of samples taken (from observation)

Table 4 showed forms and place of maize storage structures in Goncha Siso Enesie District. Farmers in the study area stored their maize grains in different form and place of storages. Based on the data which were gathered, 25% of them were stored in the form of shelled cobs, 50% in unshelled cobs with husk cover and 25% winnowed maize. About 50% of the farmers stored in door and 50% of them outdoor.

Table 4: Form and place of maize storage

Item	Descriptions	Observed storage	Percent
Form and place of maize storages	Form of storing		
	Shelled cobs	10	25
	Unshelled cobs with husk	20	50
	Winnowed maize	10	25
	Where maize stored		
	Indoor	20	50
	Outdoor	20	50

4.6. Identification of Major Insect pests in Goncha Siso Enesie

Table 5 showed the major insect pests in Goncha Siso Enese. The majority of the storages were infested with Angoumois grain moth and maize weevil during second observations and all storages were infested only by maize weevil during the last observation. During the first observation, maize storage was infested with Angoumois grain moth than maize weevil and the red flour beetle was not observed in the first observation. The red flour was observed only in one storage in the second and six storage in third observation, respectively. It was observed on highly damaged maize grains. In the first, 24, 28 and13 storages, in the second, 32, 34 and 27storages and in third observations, 40, 35 and 35 were infested with maize weevil, Angoumois grain moth and both maize weevils and Angoumois grain moth, respectively. From questionnaire 90% of the respondents were responded that the stored maize grains first infested with Angoumois grain moth and that of 10% responded maize weevil first infested. All respondents have insect pest problems.

Table5: Major insect pests of stored maize grains in the study area after two to six Month storages in different traditional storage methods in the study area

Type of pest	Number of infested storages with pest		
	First observation (after 2 months)	Second observation (after 4 months)	Third observation(after 6 months)
Maize weevil	24	32	40
Angoumois grain moth	28	34	35
Red flour beetle	-	1	6
Both maize weevil & Angoumois grain moth	13	27	35

4.7. Species compositions, abundance and status of insect pests associated with stored maize grains

Three insect pests were identified in the study area. These were maize weevil, Angoumois grain moth and red flour beetle (Table 6). Maize weevil with 100% frequency of occurrence, 55.75% abundance and 57.32% relative abundance and Angoumois grain moth with 87.5% frequency of occurrence, 31.25% abundance and 31.17% relative abundance were found to be the most frequently and abundantly detected insect pests in the study area. The red flour beetle was with 15% of occurrence, 10.25% abundant and 10.22% relative abundant and therefore it was the least abundant. The two pests (maize weevil and red flour beetle) were from order Coleoptera and the rest one was from order Lepidoptera.

Table 6: Species composition, abundance, relative abundant and status of insect pests in the study area

Types of pests	Total number of adult pests	Abundance (%)	Relative abundance (%)	Frequency (% of samples containing each species)	status
Maize weevil	223	55.75	57.32	100.00	Major
Angoumois grain moth	125	31.25	31.17	87.5	Major
Red flour beetle	41	10.25	10.22	15	Miner
Total	389				

4.8. Taxonomic positions of stored maize insect pests

Table 7: Taxonomic positions and common name of the identified insect pests of stored maize grains over 2-6 Months storage period in the study area

Common name	Order	Family	Scientific name
Maize weevil	Coleoptera	Curculionidae	*Sitophylus zaemaisMotschulsky*
Angoumois grain moth	Lepidoptera	Gelechiidiae	*Sitotroga cerealella* (Olivier)
Red flour beetle	Coleoptera	Tenebrionidae	*Tribolium castaneum* (Herbst)

Maize weevil (*Sitophylus zaemaisMotschulsky*):

It is a species of beetle in the family of Curculionidae. Its length ranges from 2.5mm to 4mm.This pest is a brown beetle which has four reddish brown spots on the wing covers. Maize weevil appears similar with rice weevil but maize weevil has more clearly marked spots on wing covers and is somewhat large in size with the ability to fly (Wikipedia). In Goncha Siso Enesie, maize weevil was the major and most abundant insect pest of stored maize grains. When it infests the grains, flours appear on them. In highly damaged grains the sound of movement was created by this pest. Both the larvae and adults can be browed inside the kernels but adults can also found on the outside of the kernels. Holes appear on damaged maize grains and adults move when the infested grains bask on the sun. Maize weevils were the most dangerous insect pests of stored maize based on the data gathered and 85% of the respondents agree that they were insect pests mostly damage the maize kernels (from questionnaire).

Figure 7.Adult maize weevils

Angoumois grain moth:

The Angoumois grain moth (*Sitotroga cerealella (*Olivier)) is the species of the Gelachiidae moth family (Wikipedia). The adult Angoumois grain moth is a small buff or yellowish brown moth and its length ranges from 5-7mm with wingspan of 10-18mm. It was the second abundant insect pests in the study area next to maize weevil but it was primary insect pest during infestation in most farmers maize storages. The larvae are the most dangerous to damage the kernels. They feed on a number of whole kernel grain. Their feeding causes a reduction in grain weight and quality. Heavy infested grains by larvae have bad smell and less attractive for consumption.

Figure 8. Adult Angoumois grain moths

Red flour beetle: The red flour beetle (*Tribolium castaneum*(Herbst)) is a species of beetle in the family of Tenebrionidae. The adults are reddish brown with about 4mm long and have a flattened body and distinctive antennae. It is the least abundant pest in the study area and observed in maize grains which are highly damaged by maize weevils and or Angoumois grain moth.

Figure 9. Adult Red flour beetles

4.9. Mean percent grain damage and weight loss assessment in the study area over 2-6 months periods

4.9.1. Mean percent grain damage

Mean percent grain damage increased when storage duration increased. The mean difference is significant at 0.05 level confidence intervals. The mean grain damages of after two, four and six month's observations were 6.13%, 13.88% and 41.55 % respectively from sample taken of all traditional storage methods in the study area. As storage periods increased levels of maize grain damage also increased (Figure 10). The highest damage was recorded after 6 months storage with 88%.

One way **ANOVA for grain damage**

Grain damage

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	27745.317	2	13872.658	82.321	.000
Within Groups	19716.650	117	168.518		
Total	47461.967	119			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: Grain damage

Tukey HSD

(I)periods	(J) periods	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
after two months	after four months	-7.750*	2.903	.023	-14.64	-.86
	after six months	-35.425*	2.903	.000	-42.32	-28.53
after four months	after two months	7.750*	2.903	.023	.86	14.64
	after six months	-27.675*	2.903	.000	-34.57	-20.78
after six months	after two months	35.425*	2.903	.000	28.53	42.32

	after four months	27.675*	2.903	.000	20.78	34.57

*. The mean difference is significant at the 0.05 level.

Homogeneous Subsets

Grain damage

Tukey HSD[a]

Periods	N	Subset for alpha = 0.05		
		1	2	3
after two months	40	6.13		
after four months	40		13.88	
after six months	40			41.55
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 40.000.

Descriptive

Grain damage

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		
after two months	40	6.13	4.746	.750	4.61	7.64	0	21
after four moths	40	13.88	6.470	1.023	11.81	15.94	0	30
after six months	40	41.55	21.004	3.321	34.83	48.27	15	88
Total	120	20.52	19.971	1.823	16.91	24.13	0	88

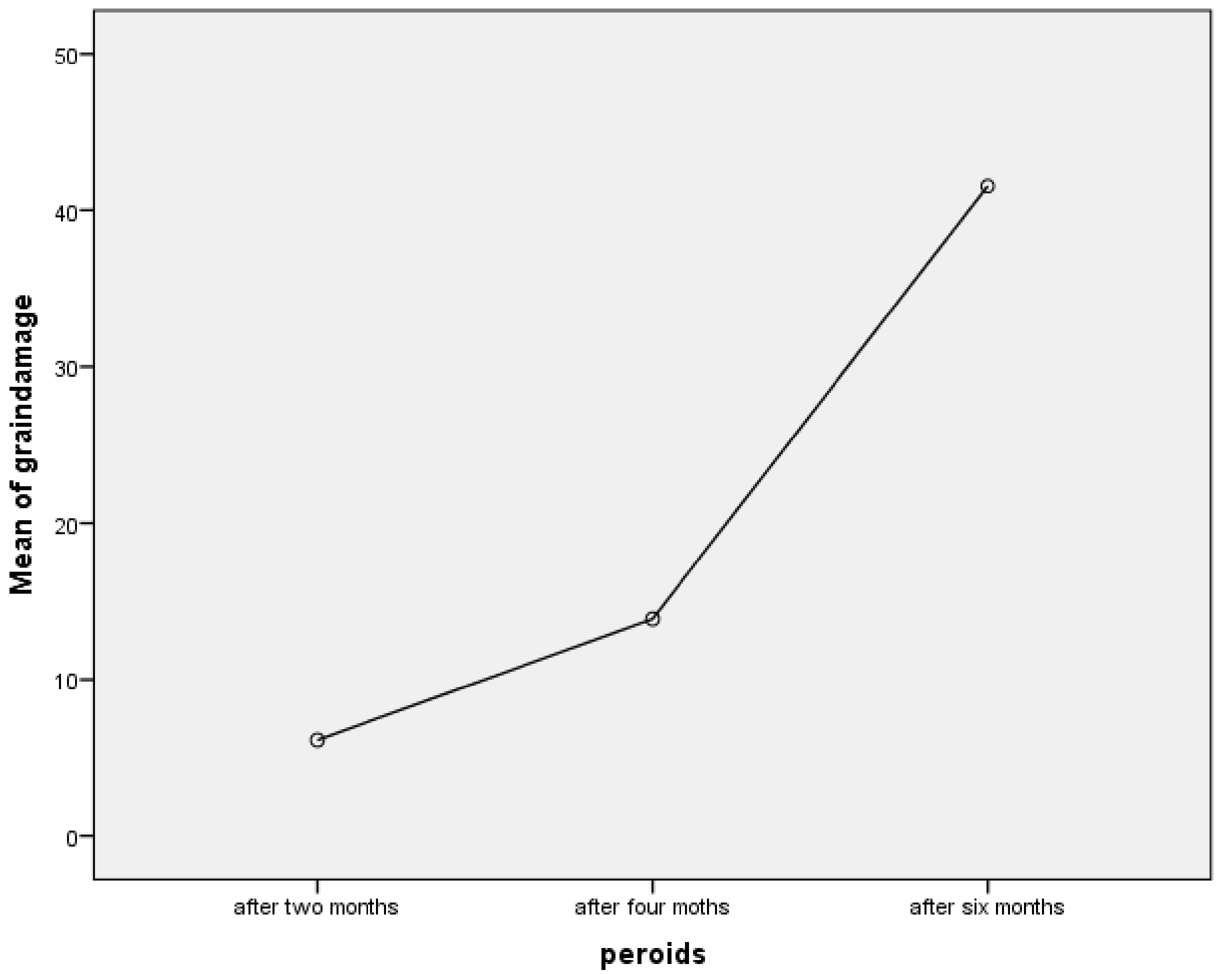

Figure 10. Grain damage over three periods

4.9.2. Weight loss

Mean weight loss increased when storage duration increased. The mean difference is significant at 0.05 level confidence intervals. The mean weight loss of after two, four and six month's observations was -11.89, -5.57 and 5.71 respectively from sample taken of all traditional storage methods in the study area. As storage periods increased weight loss also increased (Figure 11). The highest loss was recorded after 6 months storage period with 49%.

One way ANOVA for weight loss

weight loss

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	6360.591	2	3180.295	26.784	.000
Within Groups	13892.421	117	118.739		
Total	20253.011	119			

Post Hoc Tests

Multiple Comparisons

Dependent Variable: weight loss

Tukey HSD

(I) periods	(J) periods	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
After two months	After four months	-6.328*	2.437	.028	-12.11	-.54
	After six months	-17.603*	2.437	.000	-23.39	-11.82
After four months	After two months	6.328*	2.437	.028	.54	12.11
	After six months	-11.275*	2.437	.000	-17.06	-5.49
After six months	After two months	17.603*	2.437	.000	11.82	23.39
	After four months	11.275*	2.437	.000	5.49	17.06

*. The mean difference is significant at the 0.05 level.

Descriptives

Descriptive

weight loss

	N	Mean	Std. Deviation	Std. Error	95% Confidence Interval for Mean		Minimum	Maximum
					Lower Bound	Upper Bound		

After two months	40	-11.89	8.713	1.378	-14.68	-9.11	-28	2
After four months	40	-5.57	4.873	.771	-7.12	-4.01	-13	12
After six months	40	5.71	16.017	2.533	.59	10.83	-19	49
Total	120	-3.92	13.046	1.191	-6.28	-1.56	-28	49

weight loss

Tukey HSD[a]

		Subset for alpha = 0.05		
Periods	N	1	2	3
After two months	40	-11.89		
After four months	40		-5.57	
After six months	40			5.71
Sig.		1.000	1.000	1.000

Means for groups in homogeneous subsets are displayed.

a. Uses Harmonic Mean Sample Size = 40.000.

Means Plots

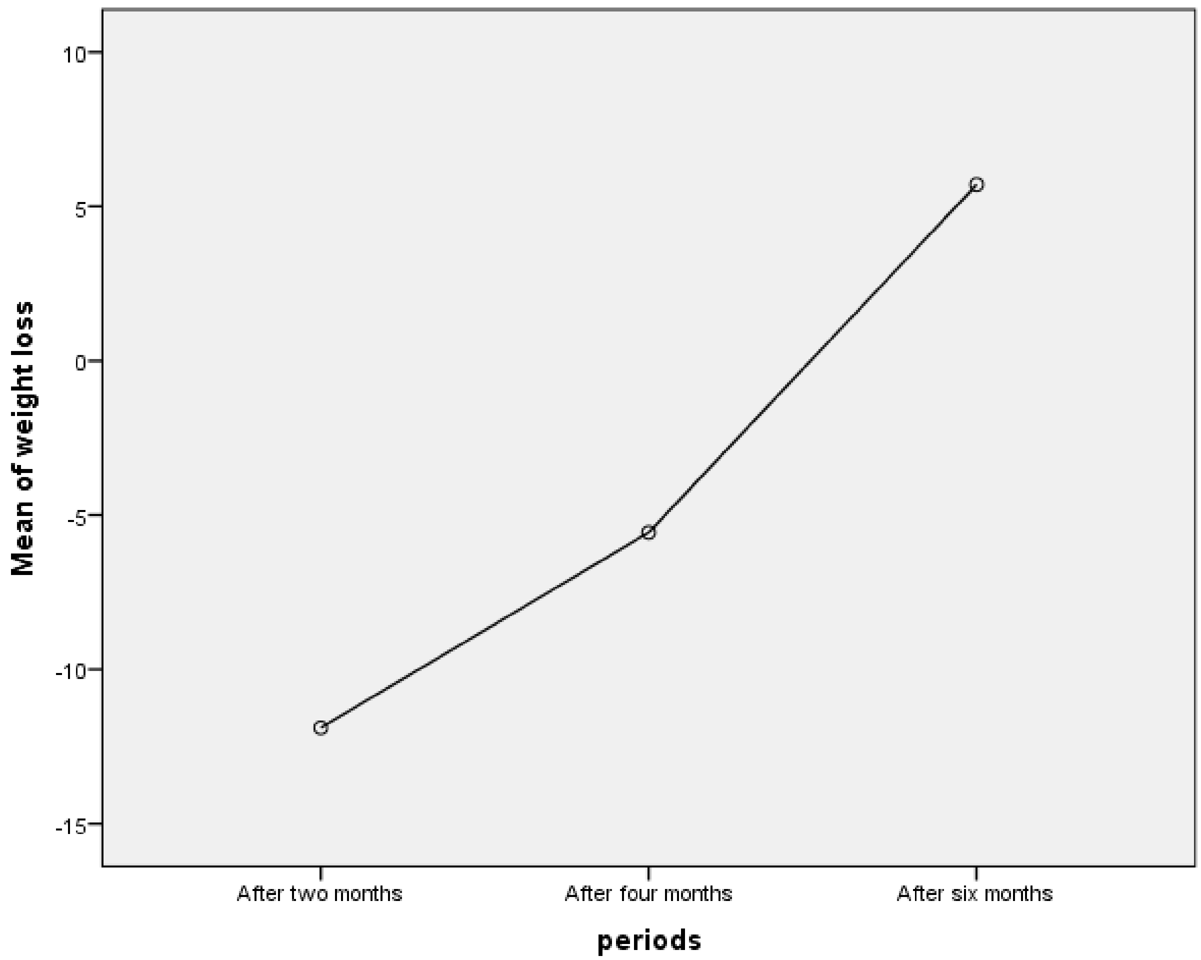

Figure 11. Weight loss across a period of time

4.10. Factors that cause post harvest infestation

Stored maize was affected by different factors in the study area (Table 8).Based on the data gathered from farmers questionnaire, excluding agricultural experts, types of storage (33.33%), length of storage (29.16%), varieties of maize(20.83%) and husk cover (10%) were the factors that cause post harvest infestation. Stored maize kernels in kot and Mamma were mostly infested with insect pests than other traditional storages in the study area so weight loss and grain damage were very high. Gotera was moderate and sacks were the least infected by insect pests (observation). Hybrid maize varieties were more susceptible to insect pests than traditional one.

Table 8: Factors that cause post harvest infestation (questionnaire)

Factors	Frequency (N=120)	Percent
Varieties of maize	25	20.83
Types of storage	40	33.33
Length of storage duration	35	29.16
Husk cover	12	10
All factors	8	6.67

4.11. Insect pest Control Methods in the study area

Farmers in the study area performed the following insect pest control methods (Table 9). Based on the data gathered from farmers 'questionnaire, sanitation (55.83%), botanical control (5%), wood ash (4.16%) and pesticides (33.33%) were insect pest control methods in the study area.

Table 9: Insect pest control methods (questionnaire)

Insect pest control methods	Frequency (N=120)	Percent
Sanitation	67	55.83
Botanical control	8	5
Wood ash	5	4.16
Pesticides	40	33.33

5. Discussions

Maize is an important cereal crop in Ethiopia, which is used for the purpose of food for humans and feed for animals. It is also one of the most suitable foods and cereal crops supplying energy for the eaters and profit for commerce man. Maize is grown in different regions of Ethiopia. To achieve the objectives of the study, 130 of the respondents were selected from 12 kebeles of the District. Out of 130 respondents, 83.08% were males who were participating more in farming activities and 16.92% were females who carried out less participating in farming activities. Farmers with age of 51-60 were more participants (36.92%) than the other age groups during survey and fewer youth participants in the farm. Moreover 35.38% of the farmers did not attend formal education and 43.07% of them attended primary education and in lesser extent 8.46% and 3.84% attended secondary and preparatory education respectively. About 9.23% of the respondents also were diploma/degree holders. The majority of the respondents had home (79.23%) which was important for co-operative working in farming works and the social problems that hinders good quality work like divorce and widow are very low and this showed as there was good working environment in the District. This outcome was similar with Emana et al. (2008) as he reported farmer's back ground determines how effective they are in producing crops. The majority of the respondents have more farming experience (45.38%) and they were elders based on the data that were gathered.

The majority of the farmers (91.67%) were performing in cultivation of hybrid maize variety only. All farmers (100%) were carrying out in cultivation of hybrid variety even though some cultivate traditional variety in addition to hybrid variety side by side. This result was dissimilar to Tolesa as he reported more than 50% of the farmers cultivated hybrid maize varieties, while local varieties were grown less 25% by local farmers. The two hybrid varieties of maize that were cultivated in the study area were BH661 and BH540. BH661 was cultivated more (66.67%) by local farmers of the District than BH540 (33.33%). According to Table 2, farmers in Goncha Siso Enesie did not cultivate traditional maize varieties only but they cultivated with hybrid varieties side by side.

Farmers in Goncha Siso Enese used different types of storage for maize based on environmental condition. These include mamma (loft) (35.83%), gotera (23.33%), kot (22.5%) and sacks (18.33%). Mamma was traditional storage structure (Figure 3) for unshelled maize cobs. It has not a protective structure from sun light and rain so the maize cobs were vulnerable by insect pests because when the temperature or sun light level increased the level of infestation and the amount of insect pest increased so the level of grain damage by insect pests increased. In addition to these, during rainy seasons the moisture creates advantages for the development of other arthropods such as worms which damage the grains on the cobs and facilitates fungal development on the grains. All mamma storages were full of insect pests and vulnerable for birds (observations). Farmers use mamma as permanent storage to minimize work load during harvesting seasons and to feed the husk for their animals during non harvesting seasons.

Gotera was built in cylindrical or rectangular forms. Based on Figure 5, it may have roof or roofless and store shelled or unshelled cobs. Even though it was well aerated it was unclean so can transmit insect pests from one harvesting seasons to the next seasons and causes early infestation of grains with insect pests. Some farmers preferred kot (22.5%) for storing the maize to guard it from pests such as monkeys and apes. The sacks were made in different sizes and may contain 50kg or 100kg.

The major insect pests in Goncha Siso Enese were maize weevils, Angoumois grain moths and red flour beetles. Maize weevil with 100% frequency of occurrence, 55.75% abundance and 57.32% relative abundance and Angoumois grain moth with 87.5% frequency of occurrence, 31.25% abundance and 31.17% relative abundance were found to be the most frequently and abundantly detected insect pests in the study area. The red flour beetle was with 15% of occurrence, 10.25% abundant and 10.22% relative abundant and therefore it was the least abundant. Maize weevils were more abundant than Angoumois grain moth. Upadhyay and Ahmad, 2011 reported that both the larva and adults of beetles damage the stored maize and they are more diversified and highly destructive in comparison to moths, in which only the caterpillars are harmful life stages that causes damage. As described by Worku et al., 2012 in Ethiopia maize weevil and Angoumois grain moth are the major cause of maize grain losses. The two pests (maize weevil and red flour beetle) were from order Coleopteran and the rest one was from order Lepidoptera. The insect pests are generally members of two major groups such as Coleoptera (beetles) and Lipidoptera (moths) (Emana and Tsedeke, 1999). The most important insect pests that cause damage to maize in the field and storage are Lepidopterous stalk borers and Coleoptrous weevils (Emana and Tsedeke, 1999). *S. zeamais* and *S. oryzae* are serious pests of cereals in tropics

(Dick, 1988). The similarities and different may be due to environmental similarities and different in which the studies were carried out.

Mean grain damage increased when storage duration increased. The mean difference is significant at 0.05 level confidence intervals. The mean grain damage of after two, four and six month observation was 6.13%, 13.88% and 41.55% respectively from all traditional storage methods in the study area. As storage periods increased levels of maize grain damage also increased. The highest damage was recorded after 6 months storage period with 88%. Mean weight loss also increased when storage duration increased. The mean difference is significant at 0.05 level confidence intervals. The mean weight loss of after two, four and six month observation was -11.89, -5.57 and 5.71, respectively from sample taken of all traditional storage methods in the study area. As storage periods increased weight loss also increased (Figure 11). The highest loss was recorded after 6 months storage period with 49%. The mean percentage grain damage and losses caused by the pests under traditional farmers' storage practices in Jimma zone were 64.5% and 58.85% (Waktol Sori and Amsalu Ayana, 2012). As they reported grain damage ranges from 54% to 75% between three to six months of storage where as weight loss varied from 41% to 80%. In both studies as storage periods increased both percent grain damage and weight losses also increased. However, there was percent grain damage and losses different because in Jimma, more insect pests were identified that caused more grain damage and losses than in the study area.

Based on the data gathered from farmers 'questionnaire, excluding agricultural experts, stored maize was affected by different factors in the study area (Table 8). Some of the respondents agreed that types of storage (33.33%) were the factors that caused post harvest infestations. Farmers in the study area used poor traditional storages and their maize was infested by insect pests. Some of the farmers responded that length of storage (29.16%) caused maize grain infestation. Moreover some of them agreed that varieties of maize (20.83%) and husk cover (10%) were the factors that cause post harvest infestation. Stored maize kernels in kot and Mamma were mostly infected with insect pests than other traditional storages in the study area so weight loss and grain damage were very high. Gotera was moderate and sacks were the least infected by insect pests (observation). Hybrid maize varieties were more susceptible to insect pests than traditional one. Traditional varieties have long growing seasons, but they are tasty and resistant to environmental conditions (Charles et al 2016). About 10% of the farmers responded that husk cover speed up level of infestation. This was dissimilar with intact husk on the cob forms a partial barrier to insect seeking to infest maize grains (Dick. 1988).

Based on the data gathered from farmers ‘questionnaire, sanitation (55.83%), botanical control (5%), wood ash (4.16%) and pesticides (33.33%) were insect pest control methods in the study area. Based on the data gathered, the majorities of the respondents agreed that sanitation (55.83%) was more important to minimize levels of infestation. Stores and their immediate surroundings must be kept clean as possible (Groot, 2004). It was necessary to clean grain storages between different crop harvests and storage to extend periods of infestation (Rajasri et al., 2015), (Kasozi, 2013). In lesser extent 5% and 4.16% of the respondents used “Bissana Kitel and Yetkimt Amed”, respectively to control their maize grain from insect pests. The exploitation of botanicals to guard stored commodities against insect pest attack have a very long history (Belmain and Stevenson, 2001; Isman, 2006). Moreover, about 33.33% of the farmers treated their storages with pesticides in the storages. Synthetic pesticides are the most efficient and effective methods for protection of stored products in Ethiopia and in another place (Emana, 1999).

6. Conclusions and Recommendations

6.1. Conclusions

The finding of this research indicated that the majority of the farmers were performing in cultivation of hybrid maize variety. Farmers used different types of storage for maize based on environmental condition. These include mamma (loft), gotera, kot and sacks.

The major insect pests that cause grain damage and weight loss were maize weevils, Angoumois grain moths and red flour beetles. Mean grain damage and weight loss increased when storage duration increased. Varieties of maize, types of storage, length of storage and husk cover were the factors that cause post harvest infestation. Traditional maize varieties were less susceptible to insect pests than hybrid varieties. Kot in living house and mamma were more vulnerable to insect pests. Gotera was moderate and sacks with pesticides were the slightest to be infested by insect pests. As storage periods increase both grain damage and weight loss increased.

Sanitation, botanical control, wood ash and pesticides were the insect pest control methods in the study area.

6.2. Recommendations

- Creating awareness for farmers to use improved and modern storage structures to enhance maize storage periods.
- Need of cleaning and disinfecting the storage structures before maize storage each year of harvesting seasons by farmers that helps to avoid levels of infestations from previous seasons.
- Agricultural experts should supply picks for farmers in appropriate cost from concerned body.
- Farmers need support from agricultural experts how they store their maize grains after harvesting seasons to decrease maize grain damage and loss by insect pests.
- Farmers should store their maize grains in sacks with pesticides and gotera to minimize level of infestation with insect pests.
- Husks should be removed from cobs in storages to minimize level of infestations by insect pests.
- Further studies on status of stored maize grain insect pests are recommended.

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Appendix-1

Addis Ababa Univrsity

College of Natural and Computitional Science

Graduate Studies

Department of Zoological Science

Focus group discussion with Department of Agriculture and Rural Development office of the district to get answers for the following questions.

1 What are the most common varieties of maize which are grown in the woreda?

2 what are the common maize storage methods which are used by farmers?

3 What are the most common insect pests of stored maize in the woreda?

4 What are the pest control methods that are used by farmers in the woreda?

Interview with DA

1. Which maize varieties are growing by local farmers in the area?
2. Are there insect pests of stored maize grains in the area?
3. What are the most common insect pests of stored maize grains in the area?
4. What control methods farmers do use for their stored maize grains from insect pests?

<u>Questionnaires to be filled by respondents(farmers)</u>

Dear respondents! This questionnaire is prepared to determine the types of insect pests of stored maize grains in Goncha Siso Enesie Woreda. The questionnaire has four parts. The first part contains the back ground of the respondents. The second, third and fourth parts are to identify the insect pests associated with stored maize grains, to examine the species compositions of stored maize grain insect pests, to find out the insect pest management techniques performed by local communities to control their stored maize grains from insect pests and to identify variety of maize and the types and form of storage structures used by local farmers to store their maize grains. Dear respondent, your response has great value on the finding of this study. So answer each question freely. Thank you.

Part- I Back ground of the respondents(Farmers)

Name_________________________ Kebele______________________________

Instruction: Mark X on your answer in the box provided.

1. Sex Male ☐ Female ☐

2. Age 18-20 ☐ 21-30 ☐ 31-40 ☐

41-50 ☐ 51-60 ☐ above 60 ☐

3. Level of education

Non Primary ☐ Secondary ☐ preparatory ☐ higher education ☐

4. Marital status A. single ☐ B. Married C. Divorce ☐ D. Widows ☐

5 experience A. 10_20 ☐ B.21_30 ☐ C. 31_40 ☐ D. above 50 ☐

Part – II Insect pests on stored maize grains

This part is concerned to identify insect pests associated with stored maize grains in Goncha Siso Enesie, Amhara National Regional State.

6 What types of insect pests that can damage the stored maize grains?

…………………………………………………………………………………………………

7 From the above insect pests which group of insect pests damage the maize grains that you stored?

....

8. How many quintals of your stored maize grains are affected by insect pests?

....

9. In average what amount of stored maize grains were affected by insect pests from the total amount of maize grains that you harvest each year?

…………………………………………………………………

10. How many types of insect pests are founded in your maize grain storage and in your villages?

11. What are the common maize storage insect pests in the area?

A. Maize weevil B. Red flour beetle C. Angoumois grain moth D. Maize weevil &

Angoumois grain mothE. All

12. From the above stored maize grains insect pests that are listed in question 11, which insect pests are first observed during infestation ofstored maize?

13. Which pest is the most dangerous?

A. Maize weevil B. Angoumois grain moth C. Red flour beetle

Part –III <u>Control mechanism of insect pest of stored maize grains</u>

1. What are insect pests? ……………………………………………………………………

2. How the insectpests did damage the stored maize grains?

……………………………………………………………

3. Do you use insect pest control method for your stored maize?

……………………………………….

4. From the followings methods of insect pest management practices, which methods do you use to control the stored maize grains from insect pests? A. physical control B. mechanical control C. Botanical D. pesticides

5. What pest management practice can be used by you and your local farmers to control the insect pests of stored maize grains other than the above methods listed on question 4?

……………………………………………………………………………………………………

6. Why necessary using any control mechanism for the insect pests on stored maize grains?

……………………………………………………………………………………………………

7. Where did you store your maize grains after harvesting?

……………………………………………………………………………………………………

8. Why did you select this place to store the maize grains?

....

9. Do you have other alternatives to store your maize grains after harvesting?

……………………………………………………………………………………………………

10. If you have, pleas mention all alternatives?

……………………………………………………………………………………………………

Part IV: Respond to the following questions carefully.

1. What varieties of maize are cultivated in this village?

A. traditional B. BH 661 C. BH 540

2. What factors increase pre/post-harvest infestation?

A. Varieties of maize grain B. types of storage D. Husk cover

E. length of storage duration F. all factors

3. What are storage structures there in the village?

A. Sacks B. Gotera C. kot D. mamma

4. What are the storage types mostly used by farmers?

A. Sacks B. Gotera C. kot D. Mamma

5. Which storage type exposed maize grain more too insect pests?

6. What life span does the storage structure have (Year)?

A. 1-2 B. 1-3 C. 4-6 D. 7-10

7. What damaged the quality of maize harvested and stored?

a. Insect pest b. rodents

8. Which variety of maize grains are more infested?

A. Traditional varieties B. Hybrid varieties

9. What form of maize storage more susceptible to insect pests?

A. Shelled cobs B. unshelled cobs C. winnowed maize

10. What insect pest management systems farmers use?

A. Traditional B. Modern

11. Which management is common and successful?

A) Traditional b) Modern

Appendix-2

Some of storage facilities in the survey sites

a.Mamma (unshelled cobs) b.Mamma (unshelled cobs)

kot inside house(shelled cobs)



a.Gotera(roofless)   b. goterawith corrugated iron roof   c. gotera with grass roof

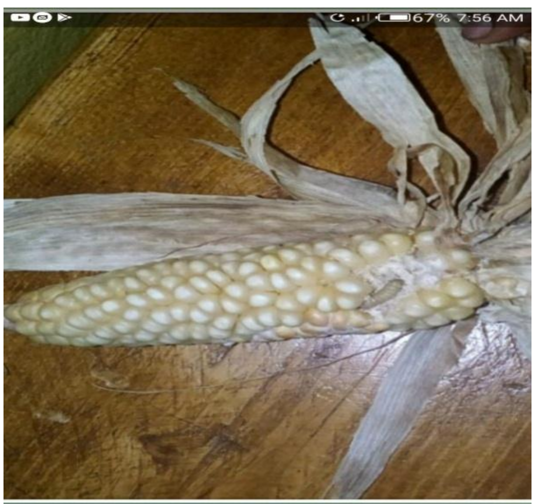
e.sacks

f. mamma on tree

Some of storages of maize in the study area during survey


Samples taken from different storages during survey

Measuring of weight loss with triple beam balance



Husk covered cob infested with worm shelling of cobs from sample taken