MAKERERE UNIVERSITY

COLLEGE OF AGRICULTURAL AND ENVIRONMENTAL SCIENCES

SCHOOL OF AGRICULTURAL SCIENCES

STORAGE INSECT PESTS DIVERSITY AT DIFFERENT LEVELS OF MAIZE VALUE CHAIN: MUKONO DISTRICT, UGANDA.

BY

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DECLARATION

I Masiko Mahafuzi do declare that this report is my own work and that it has not been produced by anyone else in this institution or any other institution.

Sign.....

Date.....12th July 2018

MASIKO MAHAFUZI

APPROVAL

This special project has been submitted for examination with my approval as university supervisor.

Sign..... Date.12/07/2018.....

PROF. TALWANA HERBERT

DEDICATION

I dedicate this research report to my beloved mother Ms.Nakaye Olivia and my sister Ndagire Evelyn for their unconditional support and unwavering love.

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I want to extend my sincere gratitude to the maize farmers, village store keepers and maize grain millers in Mukono District for their time, information and maize sample they offered me willingly and free of charge. Special thanks go Kagiri George William, my nephew who moved with me in the course of the survey and introduced me to the very many farmers I interacted with in Namubiru, Namwenga and Nangwa. I also thank my Uncle, Hajji Damulira Elias for introducing me to farmers and village stores in Mukono North. With great gratitude I thank my beloved mother, Ms.Nakaye Olivia for the unconditional support during the time of the survey and my sister, Ndagire Evelyn for the financial assistance she willingly offered to make my special project a success. Finally with great honor thank my supervisor, Prof.Herbert Talwana for his continued guidance and support during the period of the study.

God bless you all.

Masiko Mahafuzi.

ABSTRACT

Maize is a major source of food in Uganda both as a subsistence and commercial crop. Storage pests continue to devastate stored maize posing a threat to food security in many Uganda families and incomes agro processors. Maize quality and quantity is affected by these pests. The objective of the study was to determine the diversity of storage pest at three levels of the maize value chain, that is farmer level, village level and urban miller level. A survey was carried out January 2018 in the three counties of Mukono District to find out storage form, storage facilities, storage durations, and stored maize pest awareness among farmers, village maize traders and urban millers. A total of 100 farmers,10 village maize traders and 5 urban millers were sampled throughout the district. Whole grain and cob samples were collected from farmer, village traders and urban millers who were chosen randomly. Samples of each grain sample were incubated for 30 days and the emerging storage pests were identified to species level. At farmer level 50% of the samples collected had storage pests after incubation. The study showed that main storage pests affecting maize at farmer level were maize weevil (*Sitophilus zeamais*) and rice weevil (*Sitophilus oryzae*) with frequencies of 36% and 34% respectively. The survey showed that 97% of farmers are aware of the storage pest problem and only 2% of the farmers use synthetic chemical to control these pests. The rest of the farmer use soot, ash, hot pepper, urine to combat the pest problem. Majority of the farmers store their maize as cobs (55%) as opposed to storage as grain (45%) and maize is stored mainly in sacks. Majority of the samples collected from village stores had storage pests after incubation (80%) while 20% had no single pest. Maize weevil (*Sitophilus zeamais*) and rice weevil (*Sitophilus oryzae*) were the two pests found in saple from village stores. The survey showed that majority of the village stores keeps their maize in form of grain (90%) as opposed to storage as cobs. Much of this grain is stored in sacks (60%), followed by storage on bare floor (30%). It was also found that 10% of village stores use synthetic chemical for storage pest control. The study found Maize weevil (*Sitophilus zeamais*), rice weevil (*Sitophilus oryzae*), larger grain borer (*Prostephanus trunctus*), lesser grain borer (*Rhyzopertha dominica*) and granary weevil (*Sitophilus granarius*) in samples collected from urban millers at frequencies of 60%,60%,20%,20% and 20% respectively. The surveys found that majority of urban millers store their maize in form of grains (80%) and on mainly bare cemented floors (80%). 20% of the urban millers apply chemical to control maize storage pests. The chemical sited was Aluminium phosphide.

It is concluded that there is storage pest diversity increases as you move up the maize value chain, that is more pest species at urban mills level than at village stores and farm stores level. . Maize weevil (*Sitophilus zeamais*) and rice weevil (*Sitophilus oryzae*) are the commonest stored maize pest at all levels of the maize value chain.

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CHAPTER ONE: INTRODUCTION

1.1 Background

Maize, *Zea mays* is one of the most important food, feed and industrial crops worldwide, and critical to food security(Wu, F., & Guclu, H. 2013). Cereal crops play a major role in smallholder farmers' liveli-hoods in sub-Saharan Africa (SSA), with maize, being the most important food and cash crop for millions of rural farm families in the region (Midega *et al*, 2016). Similarly in Uganda maize has become one of the most grown cereal crop in farm households. This is mainly for food, fodder and commercial purposes. In Uganda maize is grown for two seasons with a great challenge of post harvest losses during storage before sale or consumption. FAO (2011) estimated food loss and wastage at 32% from farm to folk. Although food losses are being recorded at every stage in the supply chain, from production through to retail and consumption levels, the area where the greatest percentage of crop losses are recorded are pre-farm gate, where poor harvest practices, including inadequate drying, processing, and storage of crops occurs (Costa, 2015).

Insect pests are the major cause of maize losses ranking at 42% of the total loss (Bhandari *et al*, 2015). Among other cause of maize loss are weeds at 32% and diseases at 17% of the total loss.These losses threaten household food security and undermine the market returns driving farmers to seek ways to protect their grain during storage. This interests us to understand the control options the farmers take to manage the challenge and this is done through a survey. The maize weevil (*Sitophilus zeamais*), and larger grain borer (LGB) (*Prostephanus truncatus*) are the major maize storage pests in Kenya (Kimenju and Groote, 2010). Maize weevil is often confused with rice weevil (*sitophilus oryzae*) with their size differences being not consistent. However maize weevil are usually blacker than rice weevil, with fine microsculpture and is more shiny. Scutellum with lateral elevations further apart than their longitudinal length which is about half as long as the scutellum. S. zeamais and S. oryzae are found in all warm and tropical parts of the world, but S. oryzae may also be found in temperate climate (Hill, 1983) S. oryzae and S. zeamais are very important pests of cereals. In maize or sorghum, attack may start in the mature crop when the moisture content of the grain has fallen to 18-20%. Subsequent infestations in store result from the transfer of infested grain into store or from the pest flying into storage facilities, probably attracted by the odour of the stored grain (CABI, 2017) The pest status of the

Larger grain borer, Prostephanus truncatus (Coleoptera: Bostrichidae), is higher in African countries than in Latin America, its region of origin. This pest reduces the storage period of maize grain and cassava chips in granaries of small scale farmers. This reduced storage period results from larval and adult feeding with consequent shortening of the period these commodities are available for food and income generating sources. Depending on storage time, yield losses of up to 45 and 100% have been recorded for maize and cassava chips respectively , in West Africa; while 62% yield losses have been reported in Mozambique. Prostephanus truncates pest status in Africa is high and the degree of infestation and damage vary between regions. The variation in pest status is due to climatic conditions, food sources, and degree of storage infra-structure development and efficacy of control methods. Prostephanus truncatushas established in 20 African countries (Muatinte *et al*, 2014). Other maize storage pests include the lesser grain borer (*Ryzopertha dominica*). The lesser grain borer is characterized as both an internal and external feeder and is a serious pest of both whole kernel stored grain and cereal products. The adults and larvae bore into undamaged kernels of grain, reducing them to hollow husks. They are also able to survive and develop in the accumulated "flour" produced as the seeds are chewed up (Koehler and Pereira, 2018). This study comes out to find the particular storage pest species at three levels of the maize value chain, that is at farmer level, subcounty maize store and finally at the milling plant in Mukono, Uganda. Maize storage losses is one of the major reasons for farmers making hurried sale of their maize just after harvest despite unfavourable prices at a time for fear of losing much of their produce in storage

Much as storage pests cause significant loss to maize farmers, little priority has been given to their control with much attention being given to field pests. This has left local farmers with sun drying as the only option to storage pest control at farm level. Thus it becomes very important to establish farmers' awareness of the different maize storage pests that are devastating their produce to clear way for specific interventions in future to solve the pest challenge.

It is also very important to find out the existing controls and practices farmers are using to manage the maize storage pest challenge. These can be further enhanced or more effective remedies can be suggested to minimize the postharvest loss caused by Storage insect pests in maize.

1.2 Study problem

Maize is the most important cereal to both small scale farmers and agro-processors in Mukono District, where after harvest majority of the produced maize is stored in various storage structures and forms which is used to satisfy their immediate and future food needs while the rest is sold out to village traders who later sell to grain millers in the main town. Grain storage on farms and other stores thus plays an important role in ensuring food security for local populations. However, high post-harvest losses due to insect pests and inadequate storage facilities are the main setback in realizing this benefit. However, no record of previous surveys has been published for Mukono District to determine which maize storage pests are found at different levels of maize value chain and to characterize how farmers and other stakeholders respond to stored maize losses in light of their storage practices. This study presents a survey of farmers, village maize traders and grain millers in the three counties of Mukono District as a valuable tool for gaining an overview of maize storage practices in terms of storage facilities and storage forms, controls and as well determines farmer awareness of the problem. The study further investigates the identity of stored maize pests found at the three levels of the maize value chain. The information gathered has been analyzed to give a picture of the main storage problems. This information will be useful in providing a baseline for developing a new approach to controlling maize storage pests that is appropriate and effective for small holder systems in Mukono District and other parts of Uganda.

1.3 Study objectives

The overall objective of this study is to determine the diversity of maize storage pest at different levels of the maize value chain and characterize maize farmer storage practices in Mukono District, Uganda.

1.4 Specific objectives

- To identify and determine the diversity of storage insect pests at different levels of the maize value chain.
- To assess level of farmers' awareness about maize storage pests.
- To find out the different forms and storage facilities in which farmers and dealers keep their maize after harvest
- To find out the different control measures employed by farmers and maize dealers against maize storage pests.

CHAPTER TWO: LITERATURE REVIEW

2.1 Importance of maize

Maize is one of the world's leading cereal grains along with rice and wheat (Nuss *et al*, 2010). In 2008, over 750 million metric tons were produced, with the United States, European Union, China, Brazil, Mexico, and India being the world's leading suppliers (USDA/FAS, 2008). Its popularity as a crop is largely due to its diverse functionality as a food source for both humans and animals. Maize grains can be consumed off the cob, parched, boiled, fried, roasted, ground, and fermented for use in breads, porridges, gruel, cakes, and alcoholic beverages.

In sub-Saharan Africa, maize is the most important staple crop and it covers nearly 17% of the estimated cultivated land. More than 300 million people in sub-Saharan Africa depend on maize as a source of food and livelihood (Marjanovic, 2016).

In East Africa, the crop is a major staple food for a large proportion of the population, in addition to being an important animal feed. The importance of maize is centered on the large quantity of carbohydrates, proteins, vitamins and fats, contained in the kernels, making it compare favorably as an energy source with root and tuber crops. Most of this maize, in addition to being eaten directly as food, supports the local brewery industry, where flour is fermented to produce many local brews. Maize is eaten on cobs, which are either cooked or roasted. Maize flour is also used to prepare a local paste called posho, demand for which is on the increase. Posho is now increasingly served in hotels and restaurants in several urban centers including Kampala City. Maize flour is also used in making porridge for breakfast in many homes in urban areas while the maize itself is used in the manufacture of feeds for livestock. Maize is also a good source of starch and oil. According to Uganda National Household Survey (2005/06) maize was cultivated on an estimated 1.54 million hectares by about 86% of the 4.2 million agricultural households in Uganda. (Uganda Bureau of Statistics (UBoS), 2007). Owing to its importance in food security and peoples livelihood, maize becomes a crop of interest in this study.

2.2 Common maize storage pests and their damage

Larger grain borer (*Prostephanus trunctus*), maize weevil (*Sitophilus zeamais*) and Lesser grain borer (*Ryzopertha dorminica*) are the most common storage pests devastating stored maize.

2.2.1 Larger grain borer (Prostephanus *truncatus*)

Larger grain borer belongs to family Bostrichidae most of which are wood boring beetles. They are dark brown, cylindrical with rows of teeth born on the thorax. Larger grain borer is the primary pest of farm stored maize. Whole grain on the cob may be attacked both before and after harvest. When infesting stored maize cob s with the husks intact, adults begin frequently begin their attack by boring through maize cob cores, although they eventually gain access to the grain at the apex of the cob by crawling between cob and the husk. The rate of development of loose shelled is usually slower than in grain on cobs. Infestations in maize may start on the mature crop in the field, i.e. when moisture content is at or below 18%. Weight losses of up to 40% have been recorded from maize cobs stored for 6 months (Giles and Leon, 1975). In Tanzania, losses of up to 34% have been observed after 3 months storage of maize on the farm, with an average loss of 8.7% (Hodges et al., 1983). Larger grain borer is a much more damaging pest than other storage insects including Rice weevil, Maize weevil and Angoumois grain moth, under similar conditions. Larger grain borer is present in West, East and Southern Africa (Phiri and Otieno, 2008).

2.2.2 Lesser grain borer (*Rhyzopertha dominica*)

It belongs to family bostrichidae ; it is black or brown in colour with a cylindrical body. The Lesser grain borer originated in South America but is now a cosmopolitan pest especially in warm countries. It is a thermophilic pest which is particularly successful where temperatures are elevated; it is not cold hardy and there is only limited development at temperatures less than 23°C. The female Lesser grain borer lays between 300-500 eggs over a period of ca three weeks. They are laid singly or in clusters from 2-30 and are attached to the grain. Depending upon temperature the eggs hatch in 7-18 days to give white larvae with brown heads and relatively small legs. These bore into the grains where they feed and develop into fleshy forms with a typical C-shape. There are up to five molts leading to pupation in the grain. The pupal stage lasts about one week. The total life cycle lasts from 24-133 days depending upon temperature. At 26°C and 70% RH (14% MC in commodities) the life cycle lasts 45 days. Adults can live for 10 months.

Lesser grain borers are primary pests of grain and therefore attack undamaged grain rendering it susceptible to attack by secondary pests. Both the adults and larvae feed on the grain creating

floury dust and potentially leaving little but empty husks. The adults are active and may infest a large number of kernels whilst the larvae penetrate kernels and develop within the grain. Infestations in wheat can lead to reduced flour yields and will affect the quality of dough. Both volume and loaf characteristics can be adversely affected. Commodities may be tainted by insect excreta and secretions.

2.2.3 Angoumois grain moth (*Sitotroga cerealella*)

It's a lepidopteran belonging to family gelechiidae. The adult is small buff to yellowish brown moth about one third of an inch with wing span of about half an inch. The front wing is lighter color than hind wing. Both wing end in a thumb-like projection and both have fringed rear margins. The eggs are white when first deposited but soon turn red. Full grown larvae are one fifth an inch long and white with a yellow head. The area near the head is slightly larger in diameter than the posterior portion of the insect. Angoumois grain moth larvae feed on a number of whole grain kernel. Their feeding causes reduction in grain weight and quality. Heavily infested grain smells bad and is less attractive for consumption. Maize cribs infected with this insect will contain ears with small holes on individual kernels. Damage by this insect is minimal in shelled maize. However the larval stage of this insect mainly feeds on kernels of other grains other than maize. When newly harvested and infected grain is cribbed, the larvae continue to develop, pupate and emerge as adults which in turn deposit eggs on uninfected kernels.

2.2.4 *Sitophilus zeamais* (Maize weevil)

The maize weevil belongs to the insect beetle family, Curculionidae. It varies in color from dull red brown to nearly black and is usually marked on the back with four light reddish or yellow spots. The maize weevil has fully developed wings beneath its wing covers and can fly readily. The thorax is densely pitted with somewhat irregularly shaped punctures, except for a smooth narrow strip extending down the middle of the dorsal (top) side. Adults bear much similarity to the rice weevils but maize weevils are essentially larger, stronger versions with sturdier, more efficient wings. Weevils are well adapted to darkness and to movements in confined spaces and amongst stored grain (Derera *et al*, 2001). Maize weevil is an important pest especially on maize stored at the field for both food and seed (Thanda and Kevin, 2003).

2.2.5 *Sitophilus oryzae*,(Rice weevil).

The rice weevil (Figure 1) is small, 1/10 inch (2 to 3 mm) and stout in appearance. It is very similar in appearance to the granary weevil. However, the rice weevil is reddish-brown to black in color with four light yellow or reddish spots on the corners of the elytra (the hard protective forewings). The snout is long (1 mm), almost 1/3 of the total length. The head with snout is as long as the prothorax or the elytra. The prothorax (the body region behind the head) is strongly pitted and the elytra have rows of pits within longitudinal grooves. The larva is legless and stays inside the hollowed grain kernel. It is fat with a cream colored body and dark head capsule.(Koehler, 2003)

2.3 Storage pests and post harvest losses

Improving staple crop production is widely viewed as crucial for increasing food security and reducing poverty in Sub-Saharan Africa (SSA). However, it is essential to recognize that food security challenges do not simply end at harvest (Affognon *et al*, 2015). Smallholder farmers in SSA face numerous challenges after their grain leaves the field. Farmers who store grain may experience significant quantity losses due to damage from rodents, insect pests, and mold, and subsequent price discounts for damaged grain (Kaminski and Christiaensen, 2014., Kadjo *et al*, 2015 and Kadjo *et al*, 2016). Part of the reason quantity loss occurs is that many farmers lack access to effective and safe storage technology, such as airtight (hermetic) storage bags or metal silos. These technologies have the potential to positively impact household welfare but are currently not available in many rural settings (Jones *et al*, 2011 and Gitonga *et al*, 2013).

Abass *et al* (2014) stated that among all other biotic factors insect pests are considered most important and cause huge losses in the grains (30%–40%). Storage losses due to pests threaten livelihoods of farmers across Africa (Kamanula *et al*, 2011). According to studies in Kenya by Kimenju and Groote (2010a) maize weevil (Sitophilus zeamais), and larger grain borer (LGB) (Prostephanus truncatus) were the major pests in the maize. The Larger grain borer is currently found in most parts of Africa and is considered the most threatening pest, as it causes extensive damage in a very short time (Boxall, 2002 and Tefera *et al*, 2011). This study comes out to determine the common storage pests in Mukono, Uganda.

2.4 Maize storage methods for small holder systems.

Traditional storage practices in developing countries cannot guarantee protection against major storage pests of staple food crops like maize, leading to 20–30% grain losses, particularly due to post-harvest insect pests and grain pathogens. As a result, smallholder farmers end up selling their grain soon after harvest, only to buy it back at an expensive price just a few months after harvest, falling in a poverty trap. The potential impact on poverty reduction and greater livelihood security will not be realized, however, if farmers are unable to store grains and sell surplus production at attractive prices (Tefera *et al*, 2010). There is need to know how farmers are handling their maize after harvest and how this has affected the storage pest status at their farms. According to a study in western Kenya the most common methods of maize storage were gunny bags (55%), plastic bags (24%) and over fire places (32%) (Wambugu *et al*, 2009). According to FAO (1994) maize storage methods at farm/village level are categorized into short term and long term storage. Shortage methods mainly include aerial storage, storage on ground or drying floors and open timber platforms. And long term storage comprises of underground storage, solid wall bins,calabashes,gourds, cribs and jars. Other storage technologies include sacks, metal or plastic drums, concrete silos, metal silos and synthetic silos (Proctor,1994, Page 137).

According to a study in Ghana Kodwo (2015) reported that traditional storage structures for maize include platform structure, crib structure, shed storage structure, barn and Ava structure, room storage structure, Kitchen storage structure, bag storage structure, hermetic storage structure.

2.4.1 Platform Storage Structure

A platform consists essentially of a number of relatively straight poles laid horizontally on a series of upright posts with a flat top. Platforms are usually rectangular in shape, but circular or polygonal platforms are common in some countries (FAO, 2011). The platforms are usually roofed with thatch of grass, palm leaves or papyrus.

2.4.2 Crib Structure

The crib structure is a distinct improvement on the platform in that a crib has ventilated sides made of bamboo planks or even wire netting and its orientation is such that the used for dry-storing maize after harvesting. The maize crib in its many forms acts as both a dryer and a storage structure. The rate and uniformity of drying are controlled by the relative humidity of the air and the ease with which air can pass through the bed of cobs (Johnson, 2000).

2.4.3 Shed Storage structure

The shed storage structure is another simplified form of platform structure. It is mostly constructed inside a building, it may be raised just 35 - 40 cm above ground level to facilitate cleaning and inspection (FAO, 2011). Its main function is to promote drying of the harvest but not storage. Due to this reason it is unable to keep the produce for a long time without experiencing serious postharvest losses. The shed structure becomes a storage structure when the maize is kept in them long after the drying period. They are mostly unable to protect the maize against all the postharvest causes of loss such as pests, theft, harsh climatic conditions and fires (FAO, 2011).

2.4.4 Barn and Ava Storage Structures

This consists of radiating sticks constructed on the legs of wooden stalks of ten to fifteen feet. The barn, commonly referred to as Ewe Barn, is mainly used for storing maize (Boxall *et al*., 2002). They observed the maize cobs to be stacked into a compact cylinder with pointed ends of the maize directed inwards and at an angle. This is automatic arrangement following the shape of the barn. They concluded that the arrangement provided some sort of safe drainage system for rain water falling on the maize.

2.4.5 Room Storage Structure

Room storage structures are suitable for both the dry and the wet tropics. They are built to protect the grains from rain by a roof and the bottom floor made of (reinforced) concrete or (fired) bricks. These structures provide air- and watertight storage particularly when they are painted with for example chlorinated rubber-based paint, coal tar or bitumen (Hayma, 2003). Room structures are built in many forms and sizes, and are usually located near the home of the farmer. Most of the room storage structures used by smallholder farmers are improvised structures for storing husked or dehusked maize in sacks, bags or on the bare floor. This type of structure is used by farmers who produce relatively large output and have the financial means to

put up cement or brick structures. The structure offers better protection for the grains from rodents, theft and harsh external environmental conditions such as rainfall and harsh temperature (Hayma, 2003). However when the maize are placed on the bare ground or on the concrete floors, they become exposed to spores of aflatoxins and moulds which later reproduce and multiple when storage conditions become very favorable (Mejia, 2003).

2.4.6 Kitchen Storage Structure

The use of the kitchen as a storage structure is a cheaper alternative to the Room storage structure for most rural maize farmers in Ghana. This is because most farmers have adequately built structures which they used as their kitchens. So due to lack of space most of the famers store their produce in their kitchens. This practice is very common in the tropics particularly Africa (Hayma, 2003). The practice of kitchen storage is preferred because most farmers believe the heat and smoke from the kitchen would protect the maize stored from insect attack and damage (Mejia, 2003). He noticed that they place the husked or dehusked maize on the bare ground in sacks near the fireplace. Some also place them on platform or hang them directly above the fireplace. This they do by constructing an airy platform above the fireplace in such a way that the smoke and hot air can move easily through the product (Hayma, 2003).

2.4.7 Bag Storage Structure

The use of bags or sacks as storage structure is often very cheap in terms of cost and management of maize in storage. The bags can be made of different materials but the most used materials include jute, cotton, rubber/plastic, straw or sisal. These materials can be put into many different colours and sizes of bags. These bags also may be labelled and provide good conditions for fumigation practices. The bags, particularly plastic bags, are suitable for storage in the humid and dry tropics. In general jute sacks are cheaper than sacks made of cotton, plastics or sisal (Viller *et al*, 2008., Yakubu *et al*, 2011 and Anankware *et al*, 2012).The maize can be stored as husked or unhusked maize cob or as shelled grains. However the maize has to be well dried because after storage almost no further drying occurs (Hayma, 2003).

2.4.8 Hermetic Storage Structure

When a sealed container does not allow oxygen and water to move between the outside atmosphere and the internally stored grain, the internal built-up of carbon dioxide will eventually reach a level of toxicity where it is impossible for insects and moulds to survive. Such a storage

structure is referred to as hermetic (Costa, 2014). Costa further explained that hermetic storage therefore involves storage of commodities in an airtight t and watertight or low permeability environment, that provides negligible or no gas exchange between the hermetic environment and external environment.

This study will show us the maize storage methods used by local farmers, village stores and milling plants in Mukono District, Uganda.

2.5 Storage pest control measures

2.5.1 Physical control

Controlled atmospheres have been used to kill aide range of quarantine and storage pests effectively, including members of the families Tephritidae, Tortricidae, Curculionidae, Miridae and Liposcelididae (Soderstrom *et al*,1990; Ke and Kader,1992;Whiting *et al*,1992; Leong and Ho,1995; Wang *et al*, 2000). Carbon dioxide is an important factor affecting the efficacy of controlled atmosphere treatments for pest mortality. Generally, the combination of low O2and highCO2 leads to higher mortality than either gas alone because of the combined effects of anoxia and hypercarbia (Wang *et al*,2000). CO2 is efficient only when concentrations higher than 40% are maintained for long periods. Exposure periods longer than 14 days are required to kill the insects when the concentration of CO2 in the air is below 40% (Kashi, 1981 and Athie *et al*, 1998).

The following are some of the physical means of storage insect pest control;

By turning and disturbance method, sizable number of insects can be destroyed. Draping grains from a height of one meter twice a week results in killing the pests and reducing its population up to 60%. In case of Sitophilus, it is noticed that turning of grains not only kill the adults but the growth of larvae inside the grains also get arrested.

Screening of grains through wire-net sieving help in physical separation of free living insects. But if the insects separated through screening are not destroyed, they may reach the grain once again through migration.

Moisture content of grain and that of the store house is a very important factor for pest control. Food grains with moisture content below 11% are relatively resistant to insect attack whereas moisture content above 15% makes the grains susceptible to almost all types of insect pest attack.

So, it is advisable that before storing, the grains should be dried in the sun so that its moisture content should not be more than 8%. During storage grains absorb moisture especially in damp and dark store houses. To keep the moisture level low following methods have been recommended:

Before storage the grains should be properly dried, stores well ventilated, adequate space between the stacks maintained, stacks separated from the ceiling, time to time aeration of the stores prevents pest growth, use of dry bags and finally timely inspection

Application of heat and cold method is very effective measure to keep pest population under control. Refrigerated storage apart from keeping the pest population under control, maintains the quality of grains by preventing chemical and biological deterioration. Application of heat up to the lethal temperature for insects is useful but it should be highly controlled.

Polythene lined jute sacks used for storing grains provides a fair degree of barrier for insects to reach the grains.

Very intense sound may carry sufficient energy to kill the insect pest or produces changes in their behavior, including reproductive behavior. But this method is applicable to those insect pests only, which are sensitive to sound.

Infra red radiations obtained through electricity, gas or fuel in store house can kill the pests, but the method is quite costly.

(Source: http://www.yourarticlelibrary.com/zoology/preventive-methods-for-stored-grain-pests-physical-chemical-and-biological-methods/24019)

2.5.2 Chemical control

2.5.2.1Treatment of grain with contact insecticide

Most of the physical methods suggested earlier may not give total insect control. Application of chemicals, therefore, sometimes becomes essential for complete insect mortality and prevention of insect growth. It features two broad types of treatment:

- Treatment by contact insecticide
- Treatment by fumigation

This consists of covering the grain with a film of insecticide that acts on contact with insects, with effects that vary in rapidity and persistence. These products come in various forms (powders for dusting, powders to be mixed with water, liquid concentrates or fumigants) that dictate their techniques of application. For grain that is to be stored in bulk, the insecticide is incorporated directly into the grain by spraying before the silos are filled. For storage in bags, previously cleaned grain is mixed with powder or sprayed before bagging. In order to avoid re-infestation of grain stored in bags, further repeated dustings or sprayings are carried out while the bags are being stacked and during the storage period. The machinery used for dusting grain can range from the simple mechanical duster to motorized dusters, however, with this type of equipment, the grain is not treated uniformly, some areas receiving more dust than others. Spraying can be mechanical (pressure sprayer), pneumatic or thermal, and provides a better distribution of the product over the grain. In big storage centers, in order to obtain an even more regular distribution and a good coating of insecticide, the grain is fine-sprayed by a compressor equipped with a mist nozzle. Although contact systems of treatment are certainly effective on fully developed insects, they have little or no effect on the eggs or larvae. Furthermore, some residues of the product, though not highly toxic, may linger in foodstuffs. (Venkatadri, 2016).

The following are some of the common storage pest insecticides categories that have been used overtime:

2.5.2.2 Organocholines

Organochlorines are persistent in the environment and are known for bio-accumulating or building up in sediments, plants and animals. DDT was the most widely used insecticide to

protect stored maize in Brazil until 1985 (Guedes *et al*, 1995). Topical application bioassays of DDT and lindane were undertaken with 11 field strains of maize weevil, Sitophilus zeamais Motschulsky, collected from nine states in Mexico (Perez-Mendoza, 1999) in order to compare them with new insecticide treatments. Nowadays, both DDT and lindane are officially withdrawn.

2.5.2.3 Organophosphates

When the use of organochlorines was restricted, they were replaced by organophosphorus compounds, like malathion for the control of stored grain insects. Organophosphates replaced DDT, but the extensive use of malathion for pest control on stored cereals has resulted in a worldwide resistance of several species like *Tribolium castaneum* in 1961 in Nigeria or *Sitophilus zeamais* in Brazil (Guedes *et al*, 1995). The use of malathion decreased significantly after control failures in stored grain. Thus, this compound has been replaced by other organophosphorous, such as pirimiphos-methyl, chlorpyrifos-methyl, dichlorvos, etrimfos and fenitrothion

2.5.2.4 Treatment of grain by fumigation

Fumigation is a treatment that rids stored grain of insects by means of a poisonous gas called a fumigant. This substance, produced and concentrated as a gas, is lethal for specific living species. Unlike contact powders, the fumigant penetrates to the interior of the grain mass and reaches the largely invisible incipient forms (eggs, larvae) developing there. Fumigants spread throughout the area where released, therefore, used in totally sealed enclosure. Thus, when grain stored in bulk is fumigated, the bins must be perfectly airtight. For grain stored in bags, the usual method is to cover the bags with a tarpaulin whose edges are sealed to the ground or the walls. The effectiveness of fumigation depends, on the one hand, on the actual concentration of the gas and, on the other, on the length of time during which the grain is fumigated. (Venkatadri, 2016)

Two fumigants are currently used for the protection of stored foods: phosphine and methyl bromide. Methyl bromide (MeBr) fumigation of tree nuts was widely used to meet commercial phytosanitary requirements to control insect pests. However, it was used after careful consideration because of its very high toxicity to warm-blooded animals (Dansi *et al*, 1984), and its use was restricted due to its ozone depleting properties (FAO,1975). The most commonly

used fumigant is the phosphine, but its use was also limited because of increasing evidence that stored product insects were becoming resistant to the compound. This was observed in more than 45 countries (Bell and Wilson, 1995). Therefore, an effort is needed to develop a new compound to replace the conventional fumigants. The application of fumigant mixtures has been recognized as a means of overcoming the disadvantages of using a single fumigant. A combination of fumigants is advisable, because none of the common fumigants, used singly, possesses the ideal characteristics (Navarro *et al.*, 1986 and Athie *et al.*, 1998)

CHAPTER THREE: MATERIALS AND METHODS

3.1 Study area: Mukono District, Uganda

Mukono District is bordered by Kayunga District to the north, Buikwe District to the east, Tanzania to the south, Kalangala District to the south-west, Kira Town and Wakiso District to the west, and Luweero District to the north-west. The town of Mukono is about 21 kilometers (13 mi), by road, east of Kampala , the capital and largest city of Uganda. This is about 55 kilometers (34 mi) west of the town of Njeru, where the Nalubaale Power Station is located, on the Kampala–Jinja Highway. The geographical coordinates of Mukono District are 00°28'50.0"N, 32°46'14.0"E (Latitude:0.480567; Longitude:32.770567 (Google maps, 2016 and Globefeed.com, 2016)

Greater Mukono includes the current Mukono, Buikwe and Kayunga Districts. Mukono district is one of the agricultural districts of Uganda. The district is made up of four counties, that is Mukono Municipality, Mukono South, Mukono North and Nakifuuma County with a total population of 596,804 persons (Uganda bureau of statistics, 2017) Mukono is located along the Uganda-Kenya border route making it a strategic place for maize trade with neighboring Kenya.

Socio-economic survey and grain sampling was carried out in January, 2018. At this time of the year farmers have harvested their maize from the second season of the previous year. The survey and grain sampling was carried out in three counties of Mukono District: Mukono Municipality, Mukono North and Mukono South County. Villages selected in Mukono Municipality include Namubiru, Kilangira,Nsambwe and kikuba nkima. Mukono North (Villages selected): Nagalama, Gwendidde and Kalagi while Kituuza, Nakoosi and Namumira were sampled from Mukono South.This area is characterized by bi-modal rainfall pattern with the first season running from late february to late may and the second season taking on from late August to early December with average rainfall of 1390mm and annual average temperature of 21.5°C. Mukono is considered a high potential for agriculture an maize production in particular with a medium elevation of 1200m A.S.L.

3.2 Data collection

The relevant information was collected using a semi-structured questionnaire which was personally administered by the author to 100 local farmers the five counties in Mukono District, 10 village stores selecting atleast three from each county and five maize mills in Mukono Municipality central division. A maize sample of about 100g is collected from each of the respondents which is incubated for one month after which storage pests are identified from each with the aid of a hand lens.

The questionnaire was designed to collect information about farmers awareness about maize storage pests, form of maize storage, that is either as cobs or grain, common maize storage facilities, storage duration and pest control measures used by each respondent. Other socio-economic information from the respondent included his/her name, sex and location. A poster (NRI, Insects in a tropical store) containing images of different types of storage insects were presented to the respondents to help in identifying the type of insect pest species in their stores.

3.3 Data analysis

Survey data were summarized and descriptive data analysis conducted using means, frequencies and proportions using SPSS version 21 (SPSS, 2012).

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 RESULTS

4.1.1 Farmer level survey results.

At farmer level total of 100 samples were collected from villages of Kirangira (16), Namubiru (3), Kauga (2), Nangwa (19), Namwenga (22), Nagalama (15), Gwendidde (9), Kikuba nkima (6), Nasuuti (1), Total village (1) and finally Kyungu (6). 97 of the 100 farmers are aware of the identity of the different maize storage pests common in their locality.Of the 100 respondents only 2 were using chemical controls against maize storage pests. At this level most farmer store their maize as cobs (55%) and the rest as grain (45%).Every farmer sun dries his maize before storage and only 2 farmers out of 100 indicated that they synthetic Schemical storage control during storage of their maize. Dudu dust is the mainly used storage pest insecticide. 17 farmers use other controls against storage pest in maize which include hot pepper (7), garlic (2), ash (2), (conifers (2), soot (1) and urine (3). Urine, soot and ash are used mainly to preserve seed for the next planting. Majority of the farmers store their maize in sacks (82) while other store it on bare floors (9),in plastic containers (5), polythene (2) and in cribs (2).

Table 1: Insects extracted at farmer level.

Species	Common name	Sample infested	Percentage infested
Sitophilus oryzae	Rice weevil	34	34
Sitophilus zeamais	Maize weevil	36	36
Sitophilus granarius	Granary weevil	5	5
None		50	50

Of the 100 samples collected, 50 had no single pest species, 21 had two pest species of which 20 had both the rice weevil and maize weevil and only one sample had the maize weevil and granary weevil, 4 samples had all the three pests and 16 had only the maize weevil. No sample had only the rice weevil nor only the granary weevil.

4.1.2 Village store survey results.

10 village stores were sampled of from different locations, that is Nagalama (1), Nsambwe (1), Kalagi (2), Nangwa (3), Nabuuti (1), Kyungu (1), Kirangira (1). 9 out of 10 of the stores store their maize in form of grains (90%) while only 1 store stores in terms of cobs(10%). 1 out of 10 of these stores apply synthetic chemicals(10%) to control storage insect pests whereas the rest (90%) apply none. All store keepers could identify maize storage pests and majority of them store their maize in sacks (60%) followed by storage on the cemented floor (30%) and only 10% store in cribs. Other controls used by village stores include use of conifers and hot pepper. Only 2 out of 10 stores apply these controls, that is conifers (1) and hot pepper (1).

Two pest species, that is maize weevil and rice weevil were found in samples collected from village stores. 8 of the 10 samples had both pests (80%) and the rest never had a single pest (20%).

4.1.3 Urban millers survey results.

5 urban millers were sampled of which all of them were located in Mukono Municipality industrial area it was found that they are were all aware of the different storage pests and could identify them. 4 of the 5 millers store their maize in form of grains (80%) while only one could store in form of cob (20%). 4 of the 5 urban millers store their maize on bare cemented floors (80%) while the rest store in sacks (20%). Only 1 urban miller applies synthetic chemical control against maize storage pest (20%) and the chemical he uses is aluminium phosphide while the rest use none. 1 miller uses other control and that is cement that is sprinkled against the stored maize.

Table 2: Insects extracted from stored grain at urban miller level.

Species name	Common name	Samples infested	Percentage infested
Prostephanus truncatus	Larger grain borer	1	20
Rhyzopertha dominica	Lesser grain borer	1	20
Sitophilus zeamais	Maize weevil	3	60
Sitophilus oryzae	Rice weevil	3	60
Sitophilus granarius	Granary weevil	1	20

1 sample had all the four pest species (20), 1 sample had three of the pest species and 3 samples (60%) contained two pest species.

The study also found that majority of the farmers store their maize for a relatively short time from the time of harvest.82% of the sampled farmer could store their maize for a duration not more than 3 weeks as opposed to 50% of village stores and lastly only 40% of urban millers could store the maize for not more than 3 weeks time.

The study also found that farmers have less knowledge of synthetic storage pesticides and modern methods of maize storage..

4.2 Discussion of results.

This type of study is the first of its own to give an outlook on the diversity of maize storage pests and farmer storage and pest management practices in Uganda taking the case to Mukono District, Central region. The study is meant to be an eye opener for even more detailed and deeper studies on aspects of maize storage pests abundance and intensity.

From the survey it was found that farmers mainly store their maize in form of unthreshed cobs (50%) and 45% as threshed grain. This is mainly because most maize had just been harvested at the time the survey was carried out, hence it was still on its cobs. In addition maize grains still intact on cobs are less damaged by storage pests and so it's more sustainable for the farmers to keep their maize in that form.

However the statistics change when maize transits from farmers to the local village stores. By this time much of the maize (90%) is in form of threshed grain and then 80% as threshed grain at Urban millers. This may is partly due to the requirement by the purchasing store to make measurement of weight of the maize before paying and therefore it becomes incumbent of farmers to thresh their maize before sale. Threshed maize is also easy to transport as compared to unthreshed maize. The few and rare cases of unthreshed maize at village stores and urban miller is likely to be from owners maize production.

Synthetic chemical insect pest control is generally very limited at all the three levels with urban millers ranking higher at 20% followed by village stores at 10% and lastly only 2% of local farmers use such chemicals. This is mainly due low farmer awareness of the different fumigants and their unavailability in most agro-chemical shops adjacent to farmers due to low demand. Due to lack of such effective chemical controls farmers are forced to sale of grind their maize early in time to save the loss to storage pests.

Farmers store their maize mainly in sacks (82%) followed by Storage on floor (9%).However this shifts to 60% storage in sacks and 30% storage on bare floor at village store level. Further change occurs at urban millers level where 80% store on bare floor and 20% in sacks. This shift

towards bare floor from sack may be due the need to ensure convenience of operations like mixing with pesticide and avoidance of moisture accumulation that would lead to incidences of afflatoxins.

The study also found that local storage pest control methods like use of urine, ash and soot are used mainly to preserve maize seed for the next season while methods like use of garlic and hot pepper are used in protecting maize for consumption as food.

50% of samples collected from farmers never contained even a single pest. This partly because sample were just fresh from the garden and had not dried enough and thus some they ended up moulding instead of accumulating pests after the incubation period. Only 20% of the samples collected from village stores never had single pest and this is a significant reduction from 50% at farmer level. *Sitophilus zeamais* and *Sitophilus oryzae* were the most dorminant pest species at all three levels. Urban millers samples had more pest species diversity with about 5 different pest species followed by farmer level with 3 species and finally village stores with 2 pest species. Pest species in urban millers samples included *Prostephanus truncatus, Rhyzopertha dominica Sitophilus zeamais, Sitophilus zeamais* and *Sitophilus granarius.* Farmer level samples contained *Sitophilus zeamais, Sitophilus zeamais* and *Sitophilus granaries*. The significant increase in pest diversity up the maize value chain is partly due to hatching of more egg forms as time passes from the point of harvest. Piling and mixing of new stock with old stock of maize in stores with minimal chemical control causes more accumulation of different pest species. Urban millers contain more species diversity due the fact that it's a meeting point of maize from different locations with diverse types of maize storage pests.

4.3 Conclusion

Farmers in Mukono District are aware of maize storage pests and their negative effect on stored maize. However these farmers are not aware of modern storage pest control methods. Hence they still depend on traditional methods of controlling these pests which are cheaper but less effective. Such include use of soot, ash, urine, conifers and hot pepper. There no synthetic chemical pest control at farmer level and so does at village stores while there is very minimal synthetic chemical usage in urban maize millers.

Majority of these farmers store their maize in form of cobs but these changes as maize changes hands to village's store where it's mainly stored in grain form. Most farmers' store their maize is sacks after sun drying while village stores and urban millers store their maize mainly on bare cemented floors. Farmers store their maize for a very short time for fear of losing much of their produce in their stores. They are forced to process it into floor for home consumption or sell it to village stores.

There is more storage pest species diversity at urban millers than at lower levels of the maize value chain that is at farmer level and village stores. Maize weevil and rice weevil is the most abundant storage pest species at all levels of the maize value chain.

4.4 Recommendations

Based on the findings from this study, I recommend that different stakeholders in the maize industry should come out boldly to enlighten farmers about the significance of maize storage losses due to storage pests and suggest effective measures of addressing the pest challenge to them. Hermetic bags and chemical fumigants should be put with in farmers reach, that is agro-shops from which they can buy them and also get professional advice on how to use them.

Further, management interventions and effort to reduce maize post harvest loss due to storage pests should focus on the small scale farmer who is the primary producer in this case. This because storage pests at the rest of the levels are just a product or a pile of those maize storage pests already present in farmers maize right from the time of harvest. And it's these that accumulate at latter levels as time passes.

Chemical means of maize storage pest control if any should focus on Maize and rice weevil which are the predominant species in Mukono District.

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