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# 

**ABBREVIATION/ACRONYMS**

FTC Farmers Training Centers

DA Development Agency

CSA Central Statistical Agency

SPSS Statistical Package for Social Science

GPNRS Gambella people’s National Regional state

# **CHAPTER ONE**

## **INTRODUCTION**

1. **Background of the study**

Maize (Zea mays L. ssp. mays) is one of the most remarkable crops in the world. It is grown worldwide and is the most important staple crop in many countries (FAO, 1995), although a substantial quantity of maize production is destined for animal feed and biofuel (Cassidy et al., 2013). With an annual production of over 870 million tons, it is the world’s most abundantly grown cereal, surpassing wheat and rice (FAO, 2012).

A considerable amount of research is devoted to the improvement of the crop under varying climatic environments, and biotic and abiotic stresses (Bennetzen & Hake, 2009). Interestingly, the wild ancestors of maize, teosintes, were not clearly agreed on until very recently. Because there is no plant with a fruiting structure that even remotely resembles a maize ear, it was initially assumed that the ancestors were extinct (Mangelsdorf & Reeves, 1939). Indeed, the origin of maize has been the topic of considerable controversy, and various theories have been suggested (initially reviewed in Mangelsdorf & Reeves, 1939). Mangelsdorf & Reeves (1939) provided their own theory and proposed Tripsacum, a closely related grass, as a possible crossing partner with a maize-like plant that gave rise to modern maize.

Insects are the most diverse species of animals living on earth. Apart from the open ocean, insects can be found in all habitats; swamps, jungles, deserts, even in highly harsh environments such as pools of crude petroleum (Imms, 1964). Insects are undoubtedly the most adaptable form of life as their total numbers far exceed that of any other animal category. The majority of insects are directly important to humans and the environment. For example, several insect species are predators or parasitoids on other harmful pests, others are pollinators, decomposers of organic matter or producers of valuable products such as honey or silk. Some can be used to produce pharmacologically active compounds such as venoms or antibodies. Less than 0.5 percentage of the total number of the known insect species are considered pests, and only a few of these can be a serious menace to people.

Insect pests inflict damage to humans, farm animals and crops. Insect pests have been defined by Williams (1947) as any insect in the wrong place. Depending on the structure of the ecosystem in a given area and man's view point, a certain insect might or might not be considered a pest. Some insects can constitute a major threat to entire countries or a group of nations. One prominent example is the tsetse fly that puts about 100 million people and 60 million head of cattle at risk in sub-Saharan Africa due to the transmission of trypanosomiasis (ICIPE, 1997).

Herbivorous insects are said to be responsible for destroying one fifth of the world's total crop production annually. One major reason why there are pests is the creation of man manipulated habitats, that is, agroecosystems that fulfil man's needs, where crops are selected for their large size, high yield, nutritious value, and clustered in a confined area. This does not only satisfy man's demand, but provides a highly conducive environment for herbivorous insects at the same time.

In the process of artificially selecting suitable crops for human consumption, highly susceptible plants for infestation by insects are also selected. Many of the crop varieties that were developed during the past 30 years produced high yields, but, they also had poor storage characteristics (Kerin, 1994). Insect pests are capable of evolving to biotypes that can adapt to new situations, for example, overcome the effect of toxic materials or bypass natural or artificial plant resistant, which further confounds the problem (Roush and McKenzie, 1987). Crop transportation is another process where losses are common. Physical damage, grain spilling or deterioration might occur, especially if transport is prolonged. However, such losses can be avoided through proper packing, loading and handling of the crop (see Youdeowei & Service, 1983; Gwinner *et al*.,1996)

Crop products are eventually stored for varied periods of time depending on market demand, size of production and the farmer's needs. Storage is the most important and critical postharvest operation. Deterioration of the grain quality during storage can be due to improper storing conditions, which leads to contamination with fungi or insect infestation. A primary source of infestation of the stored crop is the field where the crop has grown. In many cases, infestation starts in the field. In the case of the potato tuber moth (*Phthorimaea operculella*), adult females lay eggs on the plant leaves early in the season before the crop is harvested.

With cowpeas, only a 1-2 percentage initial field infestation by *C. maculatus* may result in 80 percentage of the pods attacked after 6-8 months in storage (Youdeowei, 1989). The problem can be more complex if the crop is planted or stored nearby old granaries, which is the case with most of Africa's small scale farmers. The infestation can easily move to and from storage sites. Moreover, using the same bins year after year without proper hygiene, provides a continuous chain of infestation. Insects can hibernate or even continue to feed on wooden structures of the store or hide between holes and cracks in the walls. They can then reinvest the new crop in the same store and resume feeding.

Storing generally leads to a degree of quality change in the product due to seed's respiration, which depletes seed's nutrients over time (see Hodges, 1989; Piergiovanni *et al*., 1993; Kadlag *et al*.,1995). Combined with attack by insects and mould, rapid deterioration of the crop quality /might occur. In case of whole cereal grains, a rise in temperature is expected due to respiration, which might also occur due to insect or fungal activity. Heating leads to moisture condensation in cool areas within the grain mass. This in turn encourages further fungal growth and insect infestation (see Appert, 1987; Imura & Sinha, 1989). The exact safe moisture contents vary slightly between the different grains, however, moisture should not exceed the range of 12-13 percentage for most cereals. For pulses, intact dry grains are relatively resistant to damage, but moist, broken, split or shelled pulses are highly sensitive to infestation. On the other hand, very dry pulses with a moisture content less than 11 percentage have a breakable seed coat that cracks easily (see Youdeowei & Service, 1983; Gwinner *et al*., 1996).

In most parts of sub-Saharan Africa, harvesting of maize and other cereals is done by hand. Farmers have to wait until the crop is sufficiently dry. Some farmers leave the plant standing Provision of food has always been a challenge facing mankind. A major cornerstone in this challenge is the competition from insect pests. Particularly in the tropics and sub-tropics, where the climate provides a highly favorable environment for a wide range of insects, massive efforts are required to suppress population densities of the different pests in order to achieve an adequate supply of food. In the developing countries, the problem of competition from insect pests is further complicated with a rapid annual increase in the human population (2.5-3.0 percentage) in comparison to a 1.0 percentage increase in food production. Taking into consideration sudden problems caused by drought in places such as Africa, considerable losses of agricultural products add a serious burden to people's daily life.

The introduction of alien pests into new habitats due to the global increase of trade and transport causes another dilemma. When a pest is carried to a new geographical area, its natural enemies that keep it in check in its aboriginal home are normally left behind. This situation, in most cases, may lead to critical complications. One major example is the introduction of the spotted stemborer, *Chilo partellus* Swinhoe, into Africa coming from Asia early this century, that is now responsible for significant losses in maize and sorghum in many parts of Eastern and Southern Africa. The exotic pest may have also led to partial displacement of the native African stem borers such as *Sesamia calamistis* Hampson, *Chilo* *orichalcociliellus* Strand and *Busseola fusca* (Fuller) (Overholt *et al*., 1994; Kfir, 1997).

Recent estimates of yield losses due to stemborers alone in sub-Saharan Africa are in the INSECTS: Post-harvest Operations Page 3 neighbourhood of 20-40 percentage of the potential yield (Youdeowei, 1989; Seshu Reddy and Walker, 1990). These losses indicate the importance of stemborers as a limiting factor affecting crop productivity in Africa.

*Prostephanus truncatus* (Horn) is another exotic storage pest native to Mexico. It has recently been introduced to Africa (McFarlane, 1988; Pike *et al*., 1992), where it is currently a more destructive pest of stored maize and cassava than in its native Central America (Dick, 1988). *P. truncatus* attacks maize before and after harvest. Adults bore into the maize cob causing severe damage and weight loss. In Tanzania, maize losses of up to 35 percentages may occur due to *P. truncatus* in 5-6 months if improperly stored (Mallya, 1992), and up to 60 percentages after nine months of storage (Keil, 1988); a situation that may result in a serious famine.

Subsistence grain production is essential for the growing population of Africa. Maize is the main staple food in sub-Saharan Africa. An area of 20.7 million hectares is planted to maize in the whole of the African continent, with an average annual production of 29 million tons (Christopher *et al*., 1996). In sub-Saharan Africa, three quarters of the total production of maize is consumed as human food, which is also the case with other cereals such as sorghum and millet. The area planted by sorghum in Africa accounts for 21.8 million hectares with an average yield of 0.78 ton/ha, while 18.5 million hectares are planted with different types of millet (finger millet, pearl millet, presom and foxtail millet), yielding an annual average of 0.61 ton/ha (FAO & ICRISAT, 1996). Several factors are responsible for this considerably low level of production, of which insect pests are chiefly involved. In the Kenyan highlands, total losses due to pests in maize were estimated at 57 percentages, with insect pests being more important than diseases (Grisley, 1997). In Zimbabwe, grain damage of 92 percentages in stored maize was reported due to insect pests. Treatment with malathion reduced the damage by only 10 percentages (Mutiro *et al*., 1992). In Namibia, up to 30 percentage losses in pearl millet production can take place due to the bush cricket, *Acanthopolus discoidalis* (Wohlleber *et al*., 1996).

Root crops, such as cassava and potatoes, and pulses, which are legumes grown for their edible seeds, provide the basic source of carbohydrates and protein for people in many parts of the African continent. The area planted to cassava in sub-Saharan Africa is estimated to be 8.9 million hectare producing 72 million tons annually (Sengooba, 1994). Insect pests, in addition to fungal diseases, are responsible for 50 percentage damage in cassava (Yaninek,1994). Pulses, described as the poor man's food (Aykroyd & Doughty, 1982), are widely planted in west Africa. Cowpea, for example, is grown extensively for seeds, pods and leaves in about 15 African countries, among which Nigeria and Niger produce half of the world's total crop (Pandey & Westphal, 1989). Cowpeas are attacked by a complex of insect pests, particularly towards the end of the planting season. In storage, the bruchid, *Callosobruchus maculatus*, causes the major losses. Infestations of stored cowpeas can be as high as 90 percentages in markets and in village stores (Alebeek, 1996).

Almost 80 percentages of these food crops are produced by small scale farmers and stored on the farm (Wongo, 1996). Due to poor storage structures and conditions, severe losses in quality and quantity of stored food are inflicted annually.

# **1.2 Statement of the study**

Herbivorous insects are said to be responsible for destroying one fifth of the world's total crop production annually. One major reason why there are pests is the creation of man manipulated habitats, that is, agroecosystems that fulfil man's needs, where crops are selected for their large size, high yield, nutritious value, and clustered in a confined area. This does not only satisfy man's demand, but provides a highly conducive environment for herbivorous insects at the same time. In the process of artificially selecting suitable crops for human consumption, highly susceptible plants for infestation by insects are also selected. Many of the crop varieties that were developed during the past 30 years produced high yields, but, they also had poor storage characteristics (Kerin, 1994). Insect pests are capable of evolving to biotypes that can adapt to new situations, for example, overcome the effect of toxic materials or bypass natural or artificial plant resistant, which further confounds the problem (Roush and McKenzie, 1987).

Provision of food has always been a challenge facing mankind. A major cornerstone in this challenge is the competition from insect pests. Particularly in the tropics and sub-tropics, where the climate provides a highly favorable environment for a wide range of insects, massive efforts are required to suppress population densities of the different pests in order to achieve an adequate supply of food. In the developing countries, the problem of competition from insect pests is further complicated with a rapid annual increase in the human population (2.5-3.0 percentage) in comparison to a 1.0 percentage increase in food production. Taking into consideration sudden problems caused by drought in places such as Africa, considerable losses of agricultural products add a serious burden to people's daily life.

The introduction of alien pests into new habitats due to the global increase of trade and transport causes another dilemma. When a pest is carried to a new geographical area, its natural enemies that keep it in check in its aboriginal home are normally left behind. This situation, in most cases, may lead to critical complications. One major example is the introduction of the spotted stemborer, *Chilo partellus* Swinhoe, into Africa coming from Asia early this century, that is now responsible for significant losses in maize and sorghum in many parts of Eastern and Southern Africa. The exotic pest may have also led to partial displacement of the native African stemborers such as *Sesamia calamistis locally named as Akohga,* Hampson, *Chilo* *orichalcociliellus* Strand and *Busseola fusca* (Fuller) (Overholt *et al*., 1994; Kfir, 1997).

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Therefore, the rationale for this study is to identify major effects of insects that hamper, damage and devastate the maize crop and farmers farming style and their agricultural practices, implementation and harvesting system achievement management.

# **Objectives of the study**

## **General objective of the study**

The overall general objective of this study is to assess the effect of insects on maize crop in the study area.

## **1.3.2 specific Objectives of the study will be**

To identify the major root causes of damaging of maize crop by insects,

To find the basic solutions of effect of insects on maize crop prevention and controlling mechanisms,

To suggest on the ways of impacts of insects on maize crop yield production and involve the concerned bodies to participate on the ideas and to find out a means of bridging the gap of decrement of maize yield productions.

# **1.4. Significance of the Study**

This study is important to add values to scholars and readers as it stimulates and inspire them to undertake and carry out further researches related to effects of insects on maize crop that local farmers faced with maize yield production decrement. The study will also be important to help local farmers to pave the ways of insect pests’ prevention, preservations, controlling and improve their agricultural yield products.

This study will be useful for the local policy makers and agricultural experts to modify the ways of establishing and designing agricultural and strategies involving the newly advanced agricultural insect pest technology devices.

Finally, a wide range of end users like, farmers, DA and other agricultural programmers to establish the best effective and efficient prevention mechanisms of insect pest. This study will be useful for the local government to documented the findings in the public agricultural institute libraries as well as in the regional and woreda farmers training centers (FTC).

## **1.5. Delimitations of the study**

This study will be delimiting to assess the effects of insects on maize crop production that encountered farmer maize yield productivities in Abobo woreda.

## **1.6. Limitation of the Study**

This study will be carry out the following limitations

Due to shortage of the time given to the researcher to come across to collect enough data from the participants, researcher will face difficulty of actual documented data during data collection. Whereas there will be a problems related to resources like, budget allocation, material resources, human resources that are available on hand to support this study project work.

### **1.7. Operational Definition of terms**

**Farmer** is an individual whose primary job function involves livestock and or agriculture

**Agriculture** is the science, art and occupation of producing crops raising live stocks and cultivating the soil processing financing, marketing and distribution agricultural products.

**Farming** is the process of growing crops or keeping animals by people for food and and raw materials.

**Insect** is hexapoda any member of the largest class of the phylum arthropodan which is itself the largest of animal phyla.

# **CHAPTER TWO**

## **2. LITERATURE REVIEW**

Transgenic strategies for protecting crops against pests depend on the transfer and expression of defense genes to the crop species of interest. Among the most widely known and studied examples of induced resistance are those based on the use of the delta-endotoxin of the bacterium Bacillus thuringiensis Berliner, 1915, also known as Bt crops. This bacterium occurs naturally in soil andhas the ability to form crystal proteins during the stationary and/or sporulation phase (Vasconcelos et al., 2011). After ingestion and solubilization of the crystals in the midgut of the insect, its degradation occurs from the action of proteases, releasing delta endotoxinsor Cry proteins, which adhere to specific receptors (Carneiro et al.,2009).

The obvious tradeoff is that this trait exposes the inner seeds and makes them highly vulnerable to pathogens and herbivores. Five major genes have been proposed to be responsible for the transformation from teosintes to maize (Beadle, 1972, 1980; Doebley&Stec, 1991), of which only two, the two ‘domestication genes’ mentioned earlier, have been identified. Still, an estimated 1200 other genes were targeted during maize domestication, representing 2–4%of the maize genome (Wright et al., 2005). The transcriptomes of maize and Balsas teosinte also differ considerably (Swanson-Wagner et al., 2010, 2012; Hufford et al., 2012). Despite these genotypic and phenotypic differences, maize and teosinte still frequently hybridize (Wilkes, 1977; Hufford et al., 2013).

Contemporary maize cultivation away from the crop’s center of origin usually involves modern cultivars that are the result of hybridizations of two parental inbred lines (Duvick, 2001). Yet

hundreds of landraces are cultivated worldwide. Landraces are dynamic populations of a cultivated line that have an historical origin, a distinct identity and that lack formal crop improvement. Often, they are genetically diverse, locally adapted and associated with traditional farming systems (Camacho Villa et al., 2005). Different landraces are adapted to specific local needs and environments, producing optimal yields under specific environmental conditions, such as drought, lodging, or pest pressures. Artificial selection of crop plants for increased yield and quality has been shown to negatively influence resistance to pathogens and insects (Chen et al., 2015). This has been shown for crops as diverse as carrot (Leiss et al., 2013), bean (C\_ordova-Campos et al., 2012), and maize (Rosenthal & Dirzo, 1997), among others. This could have important consequences for crop protection, as microbes and animal pests, including insects, account for 18 and 16% of the world’s crop losses, respectively (Oerke, 2006). Most crops are bred to produce fewer toxins and thereby increase palatability. Examples include reduced concentrations of alkaloids in potato (Johns & Alonso, 1990) and lupins (Enneking & Wink, 2000), glucosinolates in Brassica crops (Mithen et al., 1987), and cucurbitacins in cucumber and squash (Paris, 1989; Nee, 1990). Maize, too, appears to have lost some of its direct defenses during selective breeding, which is more evident for modern varieties than for landraces (Rosenthal & Dirzo, 1997; D\_avila-Flores et al., 2013), although Teosinte Maize different defense traits seem to be variably affected by domestication (Bellota et al., 2013). The perennial Z. diploperennis may be more resistant than the annual Z. mays ssp. parviglumis, the latter being closer related to maize, indicating that domestication as well as life history have influenced plant resistance traits (Rosenthal & Dirzo, 1997; D\_avila-Flores et al., 2013).

Crop breeding may also have altered the emissions of volatile organic compounds (VOCs) that mediate the attraction of natural enemies, an indirect defense mechanism (Gols et al., 2011;

Rodriguez-Saona et al., 2011; Chen et al., 2015). Hence, the evident tradeoff between yield and resistance could lead to the disruption of species interactions, possibly causing reduced biological control mediated by predators or parasitoids of pest insects (Macfadyen & Bohan, 2010). For example, certain modern maize lines lack the ability to produce an important volatile that attracts insect-killing nematodes, with possible consequences for overall resistance (Rasmann et al., 2005; K€ollner et al., 2008).

In this review, we compare the various insect herbivores and pathogens that occur on maize and teosinte plants in the area of natural distribution of the teosintes (Fig. 1), and discuss the current

knowledge on the resistance mechanisms against these antagonists in wild and cultivated plants. We high light the need for measures to protect teosintes as a precious resource for crop improvement, in particular resistance against pests.

# **2.1 Maize pests and their management**

# 

Insect species that feed on cultivated maize are estimated to be more than ninety. They attack the crop as individual species or as combination of species. They attack every part of the plant, from the roots to the tassel (Meihls et al., 2012). They are thus classified into four groups: leaf feeders, stem borers, phloem feeders, and root feeders (Meihls et al., 2012). The leaf feeders are responsible

for damage of foliar and reproductive tissues.

Among them are the fall armyworm (Spodoptera frugiperda), the beet armyworm (Spodoptera

exigua), the corn earworm (Helicoverpa zea), and the grasshoppers (Melanoplus spp).

These feed on the whorls of young maize plants, producing small holes and irregular notches on the leaf margins. Stem borers damage maize by boring tunnels within the stems of the plant. They include the southwestern corn borer (Diatraea grandiosella), sugarcane borer (Diatraea saccharalis), Asian corn borer (Ostrinia furnacalis), European corn borer (Ostrinia nubilalis) and the Mediterranean corn borer (Sesamia nonagrioides). Phloem feeders on the other hand obtain nutrients from phloem sap of all aboveground plant tissues.

They are piercing-sucking insects and include the corn leaf aphid (Rhopalosiphum maidis), greenbug (Schizaphis graminum) and the bird cherry-oat aphid (Rhopalosiphum padi). A complex of Diabrotica species, among others, the western (Diabrotica virgifera virgifera), northern (Diabrotica barberi), and Mexican (Diabrotica virgifera zeae) corn rootworms attack maize roots (Meihls et al., 2012).

All those insects are maize field pests and are responsible for severe yield losses through damaging photosynthetic tissues, impeding water and nutrient movement, stem logging and breaking, leaf curling and wilting, affecting pollination, etc (Meihls et al., 2012).

Found in many environments, corn borers are primary maize pests (Meihls et al., 2012). They

feed on the pith of the stem which results in yield losses as stem damage interferes with assimilate movement to developing kernels (Samayoa et al., 2015).

Corn borers also attack ears, resulting in secondary fungal infection, leading to contamination of grain with mycotoxins like aflatoxin, which is harmful to human and animal health (Visconti et al., 1999). The maize weevil (MW) (Sitophilus zeamais), on the other hand, is among the key storage pests in maize and affects mostly susceptible genotypes leading to great losses in both quality and quantity (Gafishi Kanyamasoro et al., 2012). Classified as primary category of grain insects, both adults and larvae are internal feeders and can cause up to 80% losses on untreated maize grains (Dhliwayo and Pixley, 2003). In SSA, the most challenging stem borers are Chilo partellus and Busseola fusca and in East Africa, they are the most abundant field insect species. Of the two, C. partellus is the most competitive species able to displace any indigenous one within only two years (Sylvain et al., 2015). They account for losses ranging from 20 to 90%. In Uganda, the indigenous stemborer, Busseola fusca Fuller (Lepidoptera: Noctuidae), and the invasive Chilo partellus (Swinhoe) (Crambidae), which was introduced into Africa sometime before the 1930s, are the most important biotic constraints to cereal production (Matama- Kauma et al., 2008).

A number of strategies have been used form managing maize stem borers to either prevent or mitigate their damaging effects (Sylvain et al., 2015). Chemical control methods, although deemed to be the most effective, are expensive to most small-scale farmers and risky to humans, livestock, and the environment (Tefera et al., 2011).

In terms of efficiency, biological control ranks second. Biological control is also cost effective and environmentally safe. However, the approach is limited by its inability to sufficiently maintain pest populations below economic injury levels (Mailafiya et al., 2009). Control of stem borers has also relied on cultural methods which are easy to use and much less expensive.

The limitation of these methods however, is their inapplicability to large scale farms in addition to being difficult to time their application (Munyiri et al., 2015). A very effective approach in the control of stem borers and other lepidopteran pests is the use of Bt crops. These are crops genetically engineered to carry Bacillus thuringiensis genes. These genes produce proteins that are toxic to lepidopteran pests. They are highly specific in their mode of action leading to a narrow range of target pests (Yuan et al., 2009).

# **2.2 Insect herbivores of maize and teosintes**

Maize is attacked by a myriad of animals, from seeding until harvest and storage. Despite numerous control measures, c. 9.6% of maize production is still lost to herbivory by insects, slugs, and rodents (Oerke, 2006). Here we focus on the insect pests that occur on roots and shoots in the regions where maize and teosintes co-occur, allowing a comparative analysis of their specific defenses.

Major pests of maize in Mexico include various leaf-feeding insects (Table 1), among them the fall armyworm, Spodoptera frugiperda (Lepidoptera: Noctuidae), a polyphagous species with a

strong preference for grasses (Luginbill, 1928). The fall armyworm is specifically well adapted to cope with maize chemical defenses, which are mainly based on benzoxazinoids (Glauser et al., 2011).

The highly polyphagous corn earworm, Helicoverpa zea (Lepidoptera: Noctuidae), is also an important pest of maize (Fitt, 1989), as is the corn leafhopper, Dalbulus maidis (Hemiptera: Cicadellidae).

Although D. maidis can cause damage by itself (Bushing&Burton, 1974), its pest status is mainly a result of its activity as a vector for various plant viruses. The same is true for the corn leaf aphid, Rhopalosiphum maidis (Hemiptera: Aphididae). Weevils, thrips, and grasshoppers also occasionally become serious pests, as well as a number of leaf-feeding beetles and their root-feeding larvae.

It is generally assumed that a similar insect fauna occurs on maize and teosintes (S\_anchez Gonz\_alez & Ruiz Corral, 1995). A study performed in Guatemala revealed that most, but not all, of the insects collected on teosintes were also found on maize (Painter, 1955). Another study, comparing root insects on maize and Z. diploperennis, reported the occurrence of a number of identical insect species (Moya-Raygoza, 1987), and an overall similar insect abundance on roots of both plants. However, the number of taxa retrieved from Z. diploperennis roots was higher, possibly because this teosinte is perennial and thus provided roots all year long, while the roots of maize, as it is an annual plant, die off in winter. Indeed, there was seasonal variation for the total number of insect individuals found in maize roots, while the number of individuals in teosinte roots was fairly constant.

Additionally, the estimated total insect biomass around Z. diploperennis roots was higher than that around maize roots, indicating that insect damage was more severe on teosinte than on maize. But, as the root biomass is also higher in Z. diploperennis, this teosinte appears to be more tolerant to herbivory than maize (Moya-Raygoza, 1987; Moya-Raygoza et al., 1990). Moya-Raygoza (1994) also compared the occurrence of leafhoppers on the shoots of maize and Z. perennis and collected more taxa from Z. perennis.

Overall, teosinte populations were found to sustain a higher insect diversity, although the author did not draw conclusions concerning insect resistance of the teosinte plants. It was instead suggested that the higher diversity was the result of the fact that perennial Z. perennis provided food all year long and occurred in more diverse habitats (Moya-Raygoza, 1994).

Two recent studies extensively compared insect populations on the roots and shoots of maize and teosintes, corroborating the fact that teosintes and maize harbor a similar insect fauna (De la Paz

Guti\_errez et al., 2010; J. E. Ibarra, unpublished, but preliminary results are shared in a Mexican book by Jofre y Garfias et al., 2010).

De la Paz Guti\_errez et al. (2010) found an overall higher incidence of various arthropods on maize than on Z. mays ssp. mexicana and Z. mays ssp. parviglumis, both on roots and on shoots. While aphids were dominant on maize, teosintes were mostly colonized by thrips as well as aphids on the leaves and white beetle grubs on the roots.

The stemborer Diatraea spp. (Lepidoptera: Crambidae) and the weevil Sphenophorus spp. (Coleoptera: Curculionidae), as well as white grub, were most frequently found on teosintes, while aphids, thrips, corn leafhopper, corn rootworm (Diabrotica spp.), and fall armyworm were most abundant on maize (De la Paz Guti\_errez et al., 2010). Likewise, in another study where the incidences of fall armyworm on maize and Z. mays ssp. parviglumis were compared, maize plants were found to be more frequently infested by this important lepidopteran pest than teosinte plants (Takahashi et al., 2012). Jofre y Garfias et al. (2010) reported a high incidence of the stemborer Diatraea grandiosella, the caterpillar Agrotis ipsilon (Lepidoptera: Noctuidae), larvae of the scarab beetle Phyllophaga spp. and larvae of the weevil Sphenophorus spp. feeding on teosintes, which were also found on maize plants in the area of Michoac\_an, Mexico (Jofre y Garfias et al., 2010).

A number of other studies only reported the incidence of insects on teosintes.

A questionnaire among 63 farmers revealed that some had not noticed any insect damage on Z. mays ssp. Parviglumis plants, but others reported fall armyworm and Diatraea spp. on the teosinte Zea diploperennis Iltis, Doebley&Guzm\_an yielded the crop plant subsequently known as maize (Eubanks, 1995). Although not the first to have the idea (Vinson, 1877; Schuman, 1904; Blaringhem, 1906), Beadle (1939) was the first to propose teosintes as the direct ancestors of maize based on genetic evidence.

However, teosintes and maize are morphologically so distinct that this hypothesis has always been seriously questioned (reviewed in Doebley, 2001). The availability of modern molecular tools has allowed the exclusion of Tripsacum as an ancestor of maize, while strengthening the evidence that maize is derived from teosintes (Bennetzen et al., 2001). An extensive genetic study based on microsatellite genotyping eventually put an end to the controversy, and Balsas teosinte (Z. mays ssp. parviglumis Iltis & Doebley) was confirmed to be the progenitor of maize (Matsuoka et al., 2002). Domestication has been estimated to have begun c. 9000 yr ago

as a single event in southern Mexico (Matsuoka et al., 2002), where teosintes still grow in isolated populations, but also as a weed in maize fields (S\_anchezGonz\_alez&Ruiz Corral, 1995). Teosinte is a collective term for all taxa that comprise the genus Zea besides maize. All are annual, except for two perennial species that occur in western Mexico, Z. diploperennis and Z. perennis (Hitchc.) Reeves & Mangelsdorf.

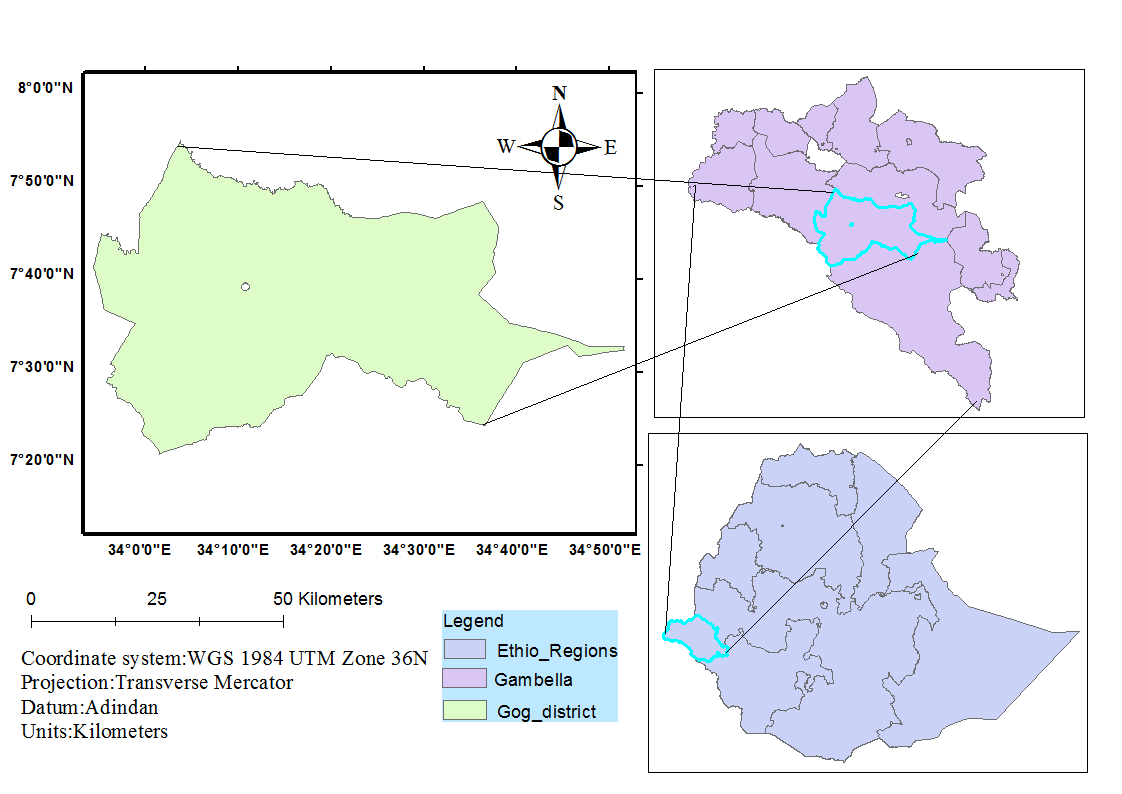
In storage, pesticides have proven effective but still present the same concerns (Mwololo et al., 2012). Pests may develop insecticide-resistance (Derera et al., 2014) and give rise to secondary insect species. All those challenges associated with pest control methods led to the reduction of their usage and success in SSA with the risk of encountering huge losses since in developing countries storage facilities are not efficient to prevent pest attacks. Therefore, the necessity of building host plant resistance (HPR) becomes obvious. To achieve this goal, several biochemical and genetic studies have been carried out with promising results.

# **CHAPTER THREE**

## **3. RESEARCH METHODOLOGY**

### **3.1 Description of the study area**

The study area is located in Gambella people’s National Regional state (GPNRS) south western part of Ethiopia at a distance of 766 kms away from Addis Ababa, between North and East. Gog Woreda is bounded to the North, North East and East by respectively. Gog woreda lies between 7°27’38”-8°18’57’’N and 34°14’59’’-35°33’49” E is one of the districts in the Gambella regional state (fig.1). The district shared great boundary with Dimma in the south, Akobo River in the south west, Jor in the west and Abobo in the north (CSA, 2007). Gog woreda is located in southern part of the Gambella region at 108 km from Gambella town and it covers an area of 1765 square kilometers (Dereje, 2003).



**(**Source; from field study GIS, 2018/9)

**Figure 1 Location map of Gog district, Gambella regional state**

# **3.1.1 Population and Settlement**

According to the Central Statistics Agency (2007), the total population of the district the 24763 of which 11503 are men and 13260 are women. Gog district cover total area of 3230.09 square kilometers with population density of 7.6 people per square kilometers. The total number of people living in the town are 10,674 (43.1%) and the remaining 14,089 (56.9%) are rural dwellers with total housing units of about 3450. Most of the people are following protestant (77.55%), Orthodox (15.08%), Muslim (2.95%), Catholic (2.6%) and the remaining (1.82 %) following traditional religion.

## **3.1.2 Physical Characteristics**

The area under the study lies in low elevated land with an elevation range between 300 to 552 meters above sea level and is characterized by flat topography with the highest point Mountain Masango with an elevation of 552 meters (CSA, 2007).

The study area falls under hot to warm semi-arid climate with two distinctive seasons of very wet and dry climate. The mean monthly maximum and minimum temperature is 35°c and 19°c respectively and the average annual temperature ranges between 20°c to 30°c. The area is also characterized by unimodal rainfall which falls very heavier during wet seasons (May-Oct) and scanty during the dry seasons (Nov-April) and the annual rainfall ranges between 800-1500mm to 1900-2100 mm (GPNRS, 2003; BoI, 2008)

The pre-Cambrian rocks that underline all other rocks in Ethiopia are covered by extensive late tertiary and quaternary deposits in the lowland of Gog Woreda, Gambella Region. The old crystalline rocks overlay the pre-Cambrian rocks in the adjacent relief and the valleys are largely composed of phyllite which uncommon chlorite (Morh, 1971). The soils in the Gog woreda are mainly chromic and pellicvertisole with Eutrichistosols in area that experience extreme seasonal flooding and there is also Eutricfluvisols on the alluvial plains of Baro river and its tributaries (FAO, 1984). Gog is one of the well-known districts in Gambella regional state in terms of fertile soil which is categorized in to four major types.

The vegetation of the study area is characterized by a range of mainly semi-deciduous tree and shrub species and grasses. The woody species and emergent trees such as Celtic toka, Diospyrosabyssinica, Malacanthaalnifolia and Zahnagolungensis are typical shrubby Spespinosa and whitfieldia elongate. These species are occurring at altitudes between 450 and 600 mask in area with mean annual maximum temperature of 35 degrees centigrade to 38 degrees centigrade and mean annual minimum temperature of 18 degrees centigrade to 20 degree centigrade, and annual rainfall of 1,300 to 1,800 mm the forest occurs mainly on sandy soils, which are well drained but have ground water not for below the surface (Hailemariam, 2011).

The economy of the study area is mainly depending largely on farming, fishing and animal rearing. Farming is a subsistence base among the Indigenous in the study area. Livestock management is predominantly practices in Gog Woreda. The main category of the livelihood is agro-pastoral such as: livestock and crop production, fishing, handing and wild food collection in which the livelihood of the community depends on. The major economic activities in the study area are livestock rearing mainly cattle, goats and sheep. Crop production (maize and sorghum) both rain fed and recessional cultivation is important. The main food sources are own crops, purchase and livestock product supplemented by wild fruits, fish and wild meat (Hailemariam, 2011).

Agriculture is one of the dominant economic activities practiced in Gambella regional state and other regional states in Ethiopia. Gog district has great potential for agricultural development of either with the application of irrigation system or using rain fed agriculture. The widespread agricultural activity in the study area enables the farmers to produce exportable agricultural products. The most common farming systems introduced in the study area include mixed farming, slash and burn farming, riverside farming and shifting cultivation (MoARD, 2009)

The types of cultivation vary greatly based on the settlement pattern for example those who are living adjacent to riverbank practiced sedentary agriculture with double cropping systems using irrigation where as those who are living apart from the riverbanks are practicing shifting cultivation using rain fed agriculture. Apart from agriculture activity, livestock rearing, fishing, bee keeping, hunting and poultry are also the most common economic activities carried out in the study area (Tamrat, 2010).

# **3.1.3 Sampling techniques**

A multi-stage stratified sampling technique will be used to select sample farmers in Gog Woreda. In the first stage, the study Woreda will be purposively selected based on the extent of maize production. Finally, 84, 44 and 76 households from a total of 3586, 1733 and 1114 households will be randomly selected from Poljay, Thata and Pochalla respectively, resulting in a total sample size of 204 households. The sample size will be distributed in each sample Kebele based on the population size.

## **3.2. Research Design**

In this research study the researcher uses both the quantitative and qualitative research approach will be employed. Mixed research approach enables to collect from various sources, interpret and analyze using appropriate techniques. Mixed method research is designed for this paper and using data gathering instruments are used to collect data using focus group discussion, key informant interview, questionnaires and observation. On the other hand, the quantitative approach will be carried out to collect data on sample households.

The participant will be choosing from people with varying educational level and social background. Respondents will be choosing as they are believed to be informed on the effect of insects on maize crops. A broad stratum of participant will be intended to access people understand, attitude, views and belief on traditional method of farming and insect pest control and conservations. Ten elders’ respondents from the village community will be purposively selected for interview. The reason for choosing this technique is such that probability sampling techniques ensure each population element to have an equal chance of being chosen as a sample unit. It is considered as meaningful way to obtain enough information from elder ancestors. The questionnaires and interview include both close and open ended question items will be developing in English and orally translated in local language for more understanding to the respondents.

## **3.3 Sample size determination**

The following formula was used in the determination of sample size (Israel, 1992), because the proportion of efficient and non-efficient is unknown the number of total population is known; hence the following formula is appropriate formula for this study

n=N1+N(e)2

Where n is the sample size needed, N is the population size of the study area (= 280576), and e is the desired level of precision (in this case, e= 7%) with the same unit of measure as the variance and e2 is the variance of an attribute in the population.

Then, the sample size (n) was calculated as follows,

n=2805761+280576(0.07)2=204

Therefore, a total of 204 households were selected for the study from four Kebeles by using random sampling method. The population size of the Woreda was obtained from the Agriculture and Rural Office of the Woreda.

# **3.4 Field Works/ Observation**

### 

According to Gorman and Clayton (2005) observation is a complex method in data collection which in its nature involves the investigator to critically observe the phenomena under its primary state using the five sense organs and scanning the situation after seeing the participants.

This method requires the investigator to actively engage in looking and observing at the condition and status of the phenomena and critical record the characteristics of the phenomena understudying. It has been widely used in various geographical researches to mention some like in (Frimpong, 2011; Bekure and Eshetu, 2014). In this research overt observation was applied to collect relevant data on the weather forecasting experiences and communities’ livelihood activity following the forecast information.

# **3.5 Source of Data and Data Collection Methods**

Qualitative and quantitative data were collected from elderly people, various fields of experts, local administrators, and sample households. The secondary data also collected from different sources such as published and unpublished documents, article using Google search engine from the internet.

# **3.6 Methods of Data Analysis**

The data collect from different sources will be analyzed by using descriptive statistics methods. The descriptive method includes percentages, tables, frequencies, median, etc. The quantitative and qualitative data will be tabulate in a way that can enable understanding factors that affect economic efficiency in maize production and effects of insect pests. SPSS (version 20) software will be used for estimating the farm-specific economic efficiency scores of maize producers in the study area. Following that the efficiency score will be taken as a dependent variable and is then coded against farmer specific, demographic, socioeconomic and institutional factors.

### **3.7 Ethical Considerations**

Prior to data collection the investigator has taken an entry letter from Jimma University department of Biology. This letter will be show to the responsible body like village leaders to get in touch with the participants within the study area.

Before the data will be collect in the field, the respondents asked about their willingness of either to take part or not to take part in the study and that of the informed consent and confidentiality. During field work the investigator will respect the ethical considerations of the participants and secure the data gather. It will be after fulfilling the above mentioned criteria that investigator gain an access to the participants in the study area and achieve the require ethics.

1. **PLAN OF ACTIVITIES**

|  |  |  |  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- | --- | --- | --- |
| S/No | Description of Activities | **Months** | | | | | | | |
| Dec. | Jan. | Feb. | Mar. | Apr. | May | Jun. | august |
| 1 | Writing of Senior Research proposal |  |  |  |  |  |  |  |  |
| 2 | Data collection and coding and analysis |  |  |  |  |  |  |  |  |
| 3 | Writing of Senior Research project |  |  |  |  |  |  |  |  |
| 4 | Printing and documenting of Senior Research Project |  |  |  |  |  |  |  |  |
| 5 | Final Senior Research Project Defense |  |  |  |  |  |  |  |  |

# **5. BUDGET BREAK DOWN**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| No | Item | Unit | Quantity | Unit price | Total Expense |
| Stationary Expense (in Birr) | | | | | |
| 1 | Questionnaires photo copy | Pcs | 2500 | 1.00 | 2,500.00 |
| 2 | Data encoding | Pcs | 120 | 10 | 1,200.00 |
| 3 | Printing | Pcs | 1500 | 1.50 | 2,250.00 |
| 4 | Paper | Ream | 1 | 128 | 128.00 |
| Subtotal | | | | | **6078.00** |
| Researcher and Enumerators’ Expense (in Birr) | | | | | |
| 5 | Data collection |  |  |  | 2000.00 |
| 6 | Transport cost |  |  |  | 422.00 |
| Subtotal | | | | | **2422.00** |
| Miscellaneous Expenses (in Birr) | | | | | |
| 7 | Research paper Binding and Photo copy | - | - | - | 1000.00 |
| Subtotal | | | | | **1000.00** |
| Grand Total | |  |  |  | **9,500.00** |

Budget Source: Gambella Regional state educational office

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