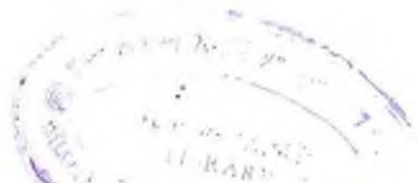


# Hybrid Maize Seed Production Manual



**Ethiopian Seed  
Association  
2014**



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ETHIOPIAN SEED



Acc 317/08

# Hybrid Maize Seed Production Manual

## Ethiopian Seed Association 2014



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**ETHIOPIAN SEED**  
ASSOCIATION



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## Preface

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High quality seed is basic and vital input for enhancing crop production and productivity. The national seed sector that comprises of different components is becoming important in the supply of seed to small farmers. The development of release of varieties in the country and introduction of commercial hybrids by private companies laid the foundation for the growing maize development in Ethiopia.

The Ethiopian Seed Association (ESA) has recently been established to support seed companies that are involved in the production and supply of high quality improved seed to small farmers in collaboration with different concerned national and international bodies. Currently the association has 21 members of private seed companies, Public seed enterprise and Farmers unions that produce mainly hybrid maize seed and very small amount of other non hybrid crop varieties. The association among its many objectives has given due focuses on up-grade knowledge and skills of members in seed production and seed business management.

Since its establishment it has under taken various measures to promote the seed sector development especially in supporting the existing and emerging seed companies and contributed to with stand the high demand of improved seed. It has also been playing a networking and facilitation role to tackle the critical problems and to strengthen the involvement of different seed actors to meet the growing national seed demand for improved and high quality seed.

Among the many crops produced in the country, maize is one of the priority and widely produced food security crop in Ethiopia today. The production of the crop has increased significantly over the last decade due to the availability of new technologies especially hybrid technologies, awareness on the important of the crops and its wide adaption in different ecological belts of the country. Recently public seed enterprise, private seed companies, and cooperative union and out grower farmers are getting widely involved in the production of hybrid varieties; however, lack of sufficient quantity of seed has been a problem. Most the seed producers have been grain producers or shifted from other business where the knowledge and skill in seed production have been limited. It is important that unlike grain producers seed producers must be technically equipped and have the key facilities and be well versed in the sector to succeed in the seed industry.

Based on its objectives the ESA, In order to support the existing and emerging seed companies and those interested and involved in the seed business this technical manual has been prepared. The manual includes pictorial presentation of the field operation, disease and insect pest management and seed quality standards that help to be competitive in the supply of quality seed to farmers. The association believes that the manual will help seed producers to use better seed production technologies so that maize farmers benefit from the high genetic potential of the hybrid they grow. The association will continue producing similar manual for the economical import crops

This manual was prepared by four professionals who are experienced in maize research and development. Dr. Benti Tolossa (varietal and crop management and, seed quality), Dr. Abraham Tadesse (storage pest), Dr Dereje Gorfu (Pre and post harvest

disease), Dr. Emanu Getu (on insect pest management) and with the support of ESA technical staff are in following and organizing the document. The ESA like to acknowledge the team for producing the manual and FAO for financial support in producing and publishing the document and the annual conferences of 2014. Integrated Seed System Development (ISSD) is also acknowledged for its technical support.

**Melaku Admasu**  
**Board Chairman, Ethiopian Seed Association**  
**Addis Ababa, Ethiopia, February, 2014**

## General Introduction

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Maize (*Zeta mays*) is one of the most important cereal crop in the world which is ranked second to wheat production, first in Africa and Latin America but third after rice and wheat in Asia. It is grown over an area of 140 million hectares with production of six million tons annually. In Ethiopia, It is grows on over 2 million hectares and ranked first among cereal in total production and productivity. The total production is estimated to be about 60 million quintals. The Hybrid maize has excellent yield potential of 120 q/ha in research and about 60 q/ha in farmer's demonstration field but national average yield is about 29.5 q/ha. All maize produced in Ethiopia is consumed directly as human food in different forms supplying the highest level of per capita food consumption amounting to about 50 kg/year and over 40% of daily calorie intake.

Maize is produced under diverse ecological conditions in different parts of the country. The reasons for such large adoption and expansion of maize cultivation in Ethiopia include:

- Adaptability to diverse environmental conditions and grows from sea level to elevations of over 2400 meter above sea level from moisture deficit to surplus areas under diverse soil conditions.
- Among all cereals grown in Ethiopia, maize is the highest yielding crop. This is because of its being very efficient converter of carbon dioxide and water to carbohydrate.
- Every part of the maize plant has economic value that produces a variety of food, feed products. Besides its food value, the green fodder



from thinning and topping and dry maize stalks and other residues can also be fed to animals. Maize stalks are also used as fuel wood and for construction purposes.

- As production and diversification of maize increases, industrial use of maize will also become important in the country.

Because of its diverse uses, substantial amount financial, material and human resources were allocated to support maize research and extension program in the country. Different varieties have been developed in the country especially hybrids that can double and triple productivity in farmers field. The main reason for rapid increase in maize production and productivity in Ethiopia is due to the adoption of hybrid maize technology and use of recommended inputs and other improved management practices.

Though maize farmers are well aware of the advantages of hybrid, lack of quality seed is one of the most important constraints to increased production and productivity. The seed production practices of Hybrid maize requires special knowledge and skill compared to grain production. So It is important to follow the right field operation and post harvest procedures. Currently private's seed producers, seed companies and farmers Unions who are members of the association are becoming important in seed business in the country.

This field guide is prepared to provide basic information for seed growers to produce high quality hybrid seed to farmers. The information contained in this field guide can be grouped into four

major categories: Hybrid maize varieties and seed production practices, insect pests and their management options, diseases and their management and major storage pest and their management options. The guide also explains quality control measures necessary to deliver superior quality seed to farmers.

# Section 1

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## Hybrid Maize Seed Production Procedures

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### 1.1 Introduction

Unlike grain production, hybrid maize seed requires a special management skill (setting planting ratio of male and female, synchronization of flowering, (adjustment of pollen shedding and silking), detasseling, rouging, harvesting crop and post harvest operation) for producing standard quality hybrid seed. Many new emerging seed companies run into problems unless they are aware of the necessary practices and learn the best techniques of producing high quality seed. This section of the manual addresses these issues and helps the seed producers learn the best techniques of producing genetically pure seed.

### 1.2. The Maize plant and developmental stage

Knowledge and understanding of the different plant growth stages is critical and useful for efficient seed production. The crop is known to be botanically unique among cereal crops. It is monoecious plant with separate male and female parts on different parts of the same plant (picture below). The male flowers are born terminally in a structure



known as tassel and the female flowers are born laterally in auxiliary shoot called ear and produces grains on lateral ears. Knowledge of the flowering period of male and female parental lines is important for the success of the good quality hybrid seed production.



**Figure 1. Tassel (male flower)      Figure 2. Ear shoot (female flower)**

### **1.2.1 Maize plant growth and development**

Maize plant development stage can be divided into four major phases that are important in field operation. These are planting to emergence, vegetative, reproductive and maturity stages.

#### **Planting to emergence**

- Germination and seedling growth depends on soil moisture, temperature, and soil aeration. Germination may start at temperatures as low as 8-10°C but occurs fastest between 28-32 °C.
- With adequate moisture, optimum temperature and proper planting depth, seedlings can emerge in 7 to 8 days and produce healthy and normal seedlings (Figure 3).





**Maize seedling 7 to 8 days old**



**11 to 12 days old**

**Figure 3. Maize seedling growth stages**

### **Vegetative stage**

This stage lasts from emergency to tasseling. It is during the vegetative stage that the plant establishes full potential of photosynthetic capacity to convert carbon dioxide and water into carbohydrates and develop strong and healthy plants. Shortage of moisture and nutrient during this stage will cause high yield reduction.

### **Reproductive stage**

The reproductive stage (tasseling and silking) is the critical stage in the life of the maize plant where pollination and seed set takes place. It is during this stage that enough moisture and plant nutrient be available

to the crop. Moisture stress during tassling and silking can reduce the final size and weight of the kernels.

- The male parent (tassels) becomes visible and shed pollen 1-3 days before the silk emerges from then cob.
- The pollen shedding starts from the spikelet's located on the central spike, 2- 3 cm from the tip of the tassel, and proceeds downwards.
- Silk (female) remains receptive for 8-10 days and anthesis continues up to 2 weeks
- Tasseling marks the transition from the vegetative phase to the reproductive phase and is less sensitive to environmental stress than silking.
- A single anther may shed 2500 pollen grains and a medium size tassel may give out 15 -30 million grains of pollen or even more. The pollen remains viable for 12-18 hours.



**Vegetative stages**

**Reproductive stages**

**Figure 4. Vegetative and Reproductive Stages**

### **Physiological maturity**

Approximately 50 to 60 days after pollination most hybrids will reach physiological maturity. This is the end of the grain filling process in which the dry weight of the grain no longer increases.

Grain filling takes place in three stages. These are:

- **Blister stage:** Kernels are filled with clear fluid.
- **Milk stage:** Kernels are filled with a white, milky fluid.

- **Dough stage:** Kernels are filled with a white paste. The top part of the kernels is filled with solid starch.

Black layer development in the kernels is an indication for the end of grain filling.. Kernels in the middle region of the ear are the first to reach the black layer followed by those at the tip ( see picture below). Kernels at the base of the ear mature last. Physiologically mature kernels contain 30 to 40 % moisture content.



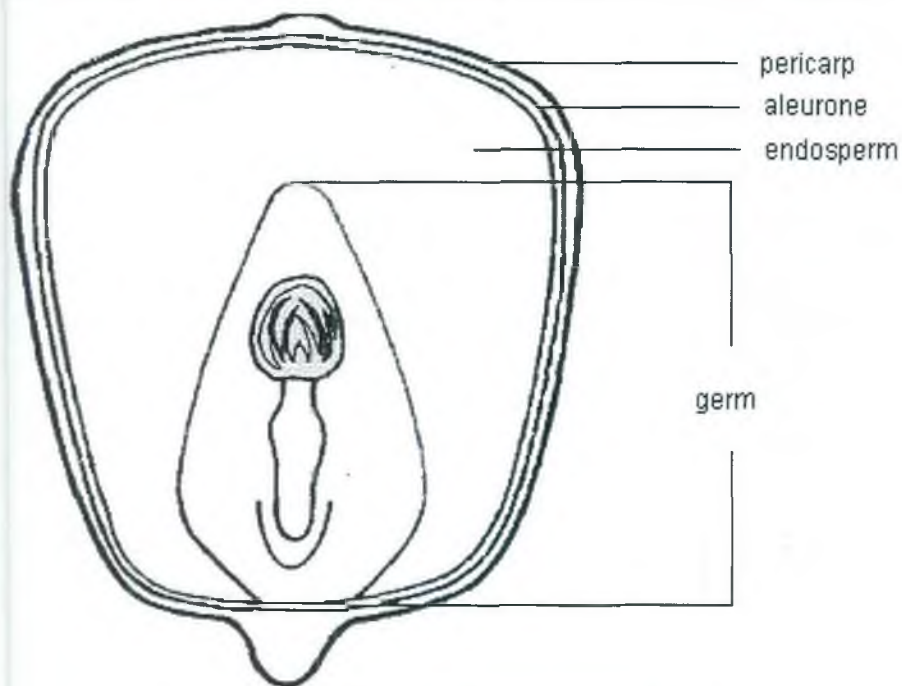
**Figure 5. Black layer formation at the tip of the kernels signifies physiological maturity and readiness for harvest.**

### **1.3. Parts of Maize Kernels and types of grain**

#### **Maize kernel**

A mature maize kernel is made up of three main parts: The seed coat or pericarp, the starchy endosperm and the embryo which will develop into a new plant (Figure 6).





**Figure 6. Maize Kernel**

The seed coat or pericarp is outer layer that protects both the endosperm and the embryo.

- It constitutes 5-6% of the kernel weight and is characterized by high crude fiber content.
- **The endosperm** is a triple fusion and constitutes over 80% of the dry weight of the seed and serves as the main source of energy for the growing seedling.
- **The embryo (germ)** is the result of fusion of male and female gametes with equal contribution (10 chromosomes from each gamete) and contains about 8% starch, 18% protein, and 33% oil. It is the embryo that grows into a new plant when placed in moist and warm soils.



## Types of Grain

Type of maize grain is classified into five groups based on the appearance and texture of its kernel. The major ones are:

- **Dent maize** is characterized by a depression or dent in the crown of the seed.
- **Flint maize**, the kernels are hard, shiny and contain little soft starch. It is generally believed that Flint maize has better storage capacity because of its hard endosperm. This generalization is not true because certain types of flint maize like 142-1e, male of BH660 are extremely soft and susceptible to weevils.
- **Pop kernels** are usually small in size and pop up when roasted and is a popular snack food in many parts of the world.

### 1.4. Hybrid maize technologies available for commercial production

Hybrid maize is an F1 generation resulting from crossing of two or more genetically different parents. Maize hybrids can be classified into two broad categories of conventional and non conventional hybrids

**Conventional hybrids** are formed from crossing of two or more genetically different inbred lines. Single cross, three way cross and double cross hybrids.

The following are types of conventional hybrids.

- Single cross-----  $A \times B$
- Three way cross-----  $(A \times B) \times C$
- Double cross-----  $(A \times B) \times (C \times D)$
- Modified single cross -----  $(A \times A) \times B$

**In non conventional hybrids**, at least one parent is not an inbred line. Variety cross, top cross and double top cross hybrids are all classified as non conventional hybrids. For example BH140 is a non conventional hybrid because the female parent (Guto LMS) is not an inbred line.

The Hybrid maize research has a history of about 30 years in Ethiopia. It was in the mid 1980s that a strong foundation was laid for the hybrid maize breeding program in Ethiopia. Currently more than 50 maize varieties including hybrid are released and registered from public research and international seed companies and some are widely produced in the country (Table 1). However, the release of BH660 and BH540 and the strong extension and popularization effort undertaken by the Sasakawa Global 2000 (SG2000) in 1993 laid the foundation of the hybrid maize technology in Ethiopia. Later on, international varieties also became important in hybrid maize production. The hybrids released also different in adaptation (1000-2000masl) in maturity (130-178 day) potential yield and other characteristics (Table 2).

In general, shifts in commercial maize production from open pollinated varieties to hybrids in 1994 and then after, accounts for sharply improved national average yields of maize from 1.5t/ha of 15 years ago to about 3.0t/ha of recent years. The introduction of hybrid seed business into the production system has also triggered the emergence and establishment of different seed industries in this country. Fifteen years ago there were only two seed companies, The Ethiopian Seed

Enterprise and Pioneer Hi-bred Seeds Ethiopia but today there are more than 30 seed companies and several farmer cooperatives that produce and market hybrid maize seed in Ethiopia. Maize hybrid seeds with excellent yield potential in farmer's field always fetch good price making seed companies to stay in the seed business for a long time.



## Ethiopian Seed Association, 2014

Table1. Commercial maize hybrids released in Ethiopia and recommendation for multiplying certified and basic seeds

Hybrid	Pedigree	Type of seed	Female parent	Male parent	Planting recommendations
<b>1., Public research institutions</b>					
BH660	A7033/ F-7215//142-1-e	Certified seed	A7033/ F-7215	142-1-e	The male parent (142-1-e) should be planted ten days before planting the female parent (A7033/F7215) or the female parent should be planted when the male parent is three leaf stages.
BH670	A7033/ F7215//144-7-b	Certified seed	A7033/ F7215	144-7-b	The male parent (144-7-b) should be planted ten days before planting the female parent (A7033/F7215) or the female parent should be planted when the male parent is three leaf stages.
BH660 & BH670	A7033 / F7215	Basic seed	A7033	F7215	The male and female parents should be planted on the same day.
BH543	SC22/124-b(109// CML197	Certified seed	SC22/124-b(109)	CML197	The male parent (CML197) should be planted five days before planting the female parent (SC22/124-b (109)), i.e., plant the female parent on the 5 <sup>th</sup> day after planting the male parent.
	SC22 / 124-b(109)	Basic seed	SC22	124-b(109)	The male and female parents should be planted on the same day.
BHQP542	CML144/CML159//CML176	Certified seed	CML144/CML159	CML176	The male and female parents should be planted on the same day.
	CML144/CML159	Basic seed	CML144	CML159	The male and female parents should be planted on the same day.
BHQPY545	CML161/ CML165	Certified seed	CML161	CML165	The male and female parents should be planted on the same day.
BH540	SC22/124-b (113)	Certified seed	SC22	124-b(113)	The female parent (SC22) should be planted seven days before planting the male parent (124-b (113)).
BH140	Gutto LMS 5/ SC22	Certified seed	Gutto LMS 5	SC22	The male and female parents should be planted on the same day.
Argane(AMH800)	Kuleni/ FS48	Certified seed	Kuleni	FS48	The male and female parents should be planted on the same day.
Venchi(AMH850)	Kii21/Kii32// FS89	Certified seed	Kii21/Kii32	FS89	The male and female parents should be planted on the same day
	Kii21/ Kii32	Basic seed	Kii21	Kii32	The male and female parents should be planted on the same day.
Jibat(AMH851)	FS59/FS69// Kii2	Certified seed	FS59/FS69	Kii2	The male and female parents should be planted on the same day
	FS59/ FS69	Basic seed	FS59	FS69	The male and female parents should be planted on the same day.
<b>2. Private Seed Companies</b>					
Phb 3253(Jabi)	-----	Certified Seed	JJ1	PA4	The Male should be planted first then plant female five days later
30G19(Shone)	-----	Certified	MTB	999	The Male should be planted first then plant female five days later
P3812W (Limu)	-----	Certified	1BMP	12GG	The Male should be planted first then plant female seven days later
P2859W (Shalla)	-----	Certified	16N3	C43	The Male should be planted first then plant female three days later
Aba Raya	-----	Certified	CC 35	SP-53	One Male parent row and all six female rows should be planted on the same day but the second male parent row will be planted after three days.



## Hybrid Maize Seed Production Manual

Table 2. Agro-ecological adaptation and other characters of released and widely produced Hybrid maize varieties, 2012

Variety	Altitude (m)	Rain fall (mm)	Plant height (cm)	Ear Placement (cm)	Days to Maturity	Seed Color	Yield (q/h)		Disease Reaction			
							Research Station	Farmers field	MSV	GLS	TLB	CLR
BH660	1600-2200	1000-1500	255-290	145-165	160	White	90-120	60-80	-	T	T	R
BH540	1000-2000	1000-1200	240-260	110-120	145	*	80-90	50-65	-	MT	MT	MT
BH140	1000-1700	1000-1200	240-265	105-120	145	*	76-85	47-60	-	MT	MT	MT
BH543	1000-2000	1000-1200	250-270	140-150	148	*	85-110	55-65	-	MT	MT	T
BHQPY545*	1000-1800	1000-1200	250-260	120-140	144	Yellow	80-95	55-65	-	T	MT	MT
BH670	1700-2400	1000-1500	260-295	150-165	165	White	90-120	60-80	-	T	T	R
BHQP542*	1000-1800	1000-1200	220-250	100-120	145	White	80-90	50-60	-	T	MT	MS
BH661	1600-2200	1000-1500	255-290	145-165	160	White	95-120	65-85	-	T	T	R
AMH-800	1800-2500	1000-1200	205-225	105-125	175	*	70-80	55-65	-	T	T	T
AMH-850	1800-2600	1000-1200	220-235	120-130	183	*	80-120	60-80	-	T	T	T
AMH-851	1800-2600	1000-1200	220-235	120-130	178	*	80-120	60-80	-	-	T	T
MH130	Low moisture	600-1000	170-190	85-100	120	White	60-70	50-60	-	-	-	-
MHQ138*	Low moisture	1000-1800	200-235	100-120	140	White	75-80	55-65	-	T	MT	MT
MH140	Low moisture	1000-1800	240-250	100-120	140	White	85-95	65-75	-	T	T	T
AbaRaya	1000-2000	1000-1200	229	-	148	White	60-100	-	-	-	-	-
P2859W (Shalla)	1000-1700	800-1000	276	-	133	White	80-100	65-80	-	-	-	-
30G19(Shone)	1000-2000	800-1200	274	-	162	White	70-110	65-80	-	-	-	-

Sources: Ministry of Agriculture, Crop Variety Register, 1998-2012.

### 1.4.3. Pictorial Identification of Parental Inbred Lines

Parental lines have specific distinguishable characteristics from other that help to easily identify in the field. For example the parental line 142-1e) of BH660 can easily be recognized by its purple tassel. Examples of some parental lines are presented Figure 7.



**142-1e**



**A 7033 x F 7215**

**Figure 7. Parental materials of BH660**



**SC 22**

**124b (113) male parent of BH540**



**124b(113)**

**Figure 8. Parental inbred lines of BH540**



**SC22**

**124b(109)**



**CML 197**



**Figure 9. Parental inbred lines of BH543**

Superior hybrids like BH660 give higher yields than open pollinated varieties such as Kuleni and Gibe 2. Maize hybrids are also more



uniform than open pollinated varieties making them suitable for mechanical harvesting. However, farmers should know that yield jump in maize hybrid is only expressed in first generation (F1) seed. If the second generation (F2) seed and subsequent generation seeds are grown, the yield of the hybrid may decrease by 25 to 30 %. Therefore, farmers should buy fresh F1 seed every year so that they get maximum yield from the seed they grow.

### **1.5 Classes of Hybrid Seed**

After a hybrid is released, it has to go through three stages of seed multiplication to reach the end users, farmers. These are breeder seed (parental lines), basic seed and certified seed.

**Breeder seed** is a class of seed produced directly under the supervision of the breeder who is the originator or owner of the hybrid. The institution from where the hybrid is released, should take full responsibility to maintain produce, and supply to the basic seed producer

**Basic seed** is derived from the breeder seed and is the source of certified seed., The basic seed of the inbred lines and of the single crosses are produced by seed companies officially licensed to produce basic seeds The company should have the experience, the facilities and the skills to assure adequate supplies of genetically pure

and standard quality seed. In basic seed production, inbred lines are multiplied once or twice before being used in single cross seed production depending on the seed need of the industry and specific regulation of the seed certification. For three way cross hybrid, the two parental lines are crossed in isolation field for the production of basic seed of the female parent. The male parent is also produced in a separate isolation field following the national seed standard.

**Certified seed:** is the last stage in the seed multiplication process that is seed sold to farmers for producing commercial crop. The seed production plots of certified seed are specially inspected and certified by the seed certification body operating in the different national regional states. Seed inspectors are stipulated to make multiple visits to production sites during and after the growing season following the national seed standard set for hybrid maize seed production.

The different classes of seed, breeder, basic and certified seed are interconnected and if one component is not operative, the entire seed program will not work properly. Therefore, breeders who developed and released the hybrid and those organizations licensed to produce the basic seed and finally those private and public companies who produce the certified seed should be able to work together for a continuous flow of new superior hybrids from breeding centers to seed producers so that maize growers get sufficient quantity of high quality seed.

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## **1.6. Management of hybrid maize seed production fields**

### **1.6.1. Selection of hybrid variety**

The seed producer should make sure that the hybrid produced is;

- Adaptable to the local conditions and has demand in the local market.
- The seed used is superior in quality and meet the minimum national seed quality standard
- Buy basic seeds from reliable basic seed producers or produce his/her own basic seeds.
- Important to test germination performance before planting

### **1.6.2 Site selection**

- Select an agro climatic belt that is suitable for the growth and development of the parental inbred lines. Agro ecological adaptation of the existing hybrids is summarized in Table 2
- Examine topography, inherent fertility, natural weed population and common pest problems before planting.
- The land should be free of volunteer maize plants and weeds and soil of the seed plot should be completely free from soil-borne diseases and insect pests.
- There should be enough moisture in the area where the hybrid seed has to be produced so that the growth of the parental inbred lines and the hybrid is not affected due to shortage of moisture.
- There should not be any problem of water logging in the field where the hybrid is grown.
- It is also desirable to avoid areas with significant movement of people and animals.
- Avoid land close to seed warehouses or other installations to prevent insect movement to the field.
- Avoid planting in fields that were previously sown to maize at least

for one years

(following the national seed standard)

- Choosing sites with access to transport to facilitate the delivery of inputs such as seeds and fertilizers as well as to deliver the harvested seed to customer

### 1.6.3 Isolation requirements in hybrid maize seed production

Maize is a cross pollinated species and pollen can be blown by wind over a long distance making it difficult for hybrid maize seed producers to prevent contamination. To avoid any chance of contamination by foreign pollen, it is desirable that then production field be separated by at least a minimum distances as set by the Ethiopian Standard Agency (Table 3).

Table 3. Isolation requirements for the three classes of seed

Category	Isolation distance
Parental lines	400 meters
Basic seed	400 meters
Certified seed	300 meters

Source: Ethiopian Standard Agency

In basic seed production, an isolation distance of more than 400 meters is required. For certified seed production, there must be at least 300 meters between the hybrid maize seed production field and the nearest commercial maize plot. For example, in BH660 certified seed production, male and female planting needs to be staggered to ensure synchronization of the male and female flowers. The female



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- Choosing sites with access to transport to facilitate the delivery of inputs such as seeds and fertilizers as well as to deliver the harvested seed to customer

### 1.6.3 Isolation requirements in hybrid maize seed production

Maize is a cross pollinated species and pollen can be blown by wind over a long distance making it difficult for hybrid maize seed producers to prevent contamination. To avoid any chance of contamination by foreign pollen, it is desirable that then production field be separated by at least a minimum distances as set by the Ethiopian Standard Agency (Table 3).

Table 3. Isolation requirements for the three classes of seed

Category	Isolation distance
Parental lines	400 meters
Basic seed	400 meters
Certified seed	300 meters

Source: Ethiopian Standard Agency

In basic seed production, an isolation distance of more than 400 meters is required. For certified seed production, there must be at least 300 meters between the hybrid maize seed production field and the nearest commercial maize plot. For example, in BH660 certified seed production, male and female planting needs to be staggered to ensure synchronization of the male and female flowers. The female

single cross of BH660 should be planted when the male parent (142-1e) attains three leaf stages.

There are several factors that can affect isolation distances. These are:

- Natural barriers like big trees or mountains may reduce contamination by foreign pollen.
- An abundant supply of pollen from the male parent at the right time reduces contamination of foreign pollen.
- Differential flowering time is effective in isolation if silks of the female parents are not receptive when contaminating pollen is present.
- Dry weather during pollination can increase the chance of contamination by foreign pollen.
- A major problem which is often a cause of contamination from foreign pollen is wind, which can carry maize pollen from a long distance.

#### **1.6.4. Land preparation**

A seed crop warrants greater care and more inputs than a grain crop. In hybrid maize seed production, extra care and attention must be given to parental inbred lines as they tend to be weaker and more susceptible to environmental stresses. Therefore, the field management should permit the expression of genetic potential of the inbred lines so that maximum seed yield is obtained from the area planted.

Suggestions for hybrid maize seed bed preparations:

- Have the soil ready for planting two weeks in advance in order to allow weed seeds to germinate



- The seed bed should be uniformly prepared and labeled for irrigated areas for good stand establishment.

### 1.6.5 Planting

- Chemical treated hybrid maize seed should be planted in a well soaked soil to avoid partial germination and subsequent rot due to insufficient moisture.
- Generally, early planting in the season has been observed to be the most important single factor in increasing yield and escaping pest attack.
- Depth of planting maize is important in placing the seed in contact with the moist soil and protecting it against rodents, birds and drying. Usually 5-7 cm is considered ideal depth of planting. Very deep planting retards germination. In moisture stress areas maize may be planted by placing the seed deeper than normal and the planting hole should be covered with a small amount of soil.
- Spacing between rows and between seeds should be similar to commercially grown plant populations. However, 5 to 10% lower population density ensures good seed set and development. Slightly lower population density will allow full expression of the plant type to aid in identification of desirable plants and to eliminate off types. Recommended spacing for late and intermediate female parent is usually 75 cm x 20/25 cm between seeds with plant population of 53,000 to 66,000/ha depending on the type of the parents planted. The male parent however could be planted slightly at higher population.
- The seed rate depends on seed (female) to pollen (male) ratio. Proportion of male and female in maize are 1:3 or 2:6 depending on the pollen producing ability of the male parent. The seed rates should also be calculated separately for the male and the female parents.

**For example: Amount of basic seed required to plant 50 hectares of a three way cross hybrid, BH661. One fourth of the 50 hectares means 12.5 hectares will be planted to the male parent and seed required at 25 kg/ha will be 3.12 quintals. For the female parent that will be planted on 37.50 hectares, seed required will be  $(37.50 \times 25 \text{ kg}) = \underline{9.38 \text{ quintals}}$ .**

- To avoid mixtures of male and female seeds while planting, seeds of female parents may be treated with a red dye, and male parents with a green dye. Similarly, female parents may be placed in red striped bags, and male parents in green striped bags. Staking the male rows prior to planting also helps in reducing errors caused during planting
- In hybrid maize seed production, border rows of the male parent are required to provide abundant pollen to female rows and serve as a guard row for the plot.

#### **1.6.6 Female to Male Ratios**

- Male and female parents should be planted in the correct row for effect seed production. The most commonly used ration is 6:2 and 3:1
- For better seed yield, ensuring synchrony between female and male parents to obtain good seed set. For example BH660 require staggered planting as their female and male parents do not nick. Any where female single cross parents of the three hybrids should be planted when the male parent attains three leaf stages. Please

refer to Table 1 for more information on the staggering dates of the popular maize hybrids in Ethiopia.

- Hybrid maize seed is only harvested from the female rows. Better seed yield from the female parent is expected when we plant a minimum number of male rows but sufficient pollen production to ensure a good seed set in the entire field.
- The male row should be quickly removed from the field just after it has finished pollination. Removal of the male parent provides more space, and solar interception for better performance of the female parent.

### 1.6.7 Fertilizer requirement

Maize should be supplied with the correct amount of fertilizer especially at early stage, flowering, and grain fill that it can produce high seed yield. Maize seedlings are like children; they must be fed and protected until they can take care of themselves. For this reason fertilizer is best absorbed by the small plants if it is placed in the soil near the seed at the time of planting.

Based on recommendation for maize production belt in the country (Table 4), Phosphorous (P) fertilizer is applied in the form of Diammonium phosphate planting, whereas Nitrogen (N) fertilizer is applied in the form of urea in one, two or three splits depending on the agro-ecology. For highland maize for instance, the recommended N fertilizer rate was applied in three splits, one-third at planting, one-third at knee height and one-third at tasseling (flowering). However, for mid-altitude sub humid maize growing environments, N is



applied in two splits, half at planting and half at knee height. For moisture stress environments the full dose of N is applied at knee height.

Table 4: Production belt, soil information and current recommended NP rates of maize.

Maize belts	Soil type	Soil reaction	Recommended (Urea/DAP) (kg/ha).
Bako, Jimma, Burie, Wenberma	Nitosols	Acidic	200/100
Shebedino, Halaba, Shashemene, Awassa	Fluvisols Andosols	Near neutral	200/100
L/Adiabo	Cambisols	Near neutral	150/100
Melkasa (moisture stress)	Sandy soil	-----	50/100



**Figure 10. Urea application and inter row cultivation of maize. Timely fertilizer application results in good crop performance**

### 1.6.8. Irrigation

Good quality seed is produced under supplementary or direct irrigation in lowland areas where there is no sufficient rainfall. So, if the seed is to be produced under irrigation, water should be applied based on soil texture, depth, climatic conditions and the crop

development stages. Irrigating early in the season is beneficial for uniform stand establishment. Under dry conditions Irrigation applications start before planting and continue every 4 to 5 days intervals. However, it is critical at flowering stage.

### **1.6.9 Weed control**

- The maize growing belts of Ethiopia are infested by many hard to control sedge and grassy weeds. The lowlands are particularly invaded by invasive species such as *parthenium* and similar weeds.
- Twice hand weeding (the first one at 25 - 35 days after planting and the second at knee height and slashing weeds at flowering stage is recommended for proper weed control.
- In chemical weed control, pre-emergence herbicides such as primagram, Gessaprim or Laso + Atrazine at the rate of 3-5 liter per hectare supplemented by hand weeding gives good result in maize production.
- In general, making maize seed production fields free of weeds facilitates rouging, detasseling, field inspection and harvesting.

### **1.6.10 Rouging**

It is careful and systematic removal of undesirable plants that do not conform to the varietal characteristics from a seed production field. It plays an important role for maintaining the genetic purity of hybrids. It should be completed in both parents before the parental lines start flowering. The off type plants differ in presence or absence of pigment on stem, cob silk color, plant height, glumes color, and tassel orientation ( see picture below).



**Figure 11. Male parent of BH660 (142-1e) grown in the female rows can be easily recognized by its purple color and should be removed quickly**

Rogues which differ from the normal plant population, diseased or dissimilar may cause deterioration in seed stocks and therefore should be removed before shading pollen.

- Rouging in maize seed production has to be carried out at all stages from germination to harvest
- Rogue off type plants which deviate from the given genotype in respect to root and stalk development (see picture blow), plant type, pigmentation, leaf and stem pubescence, etc. Effective rouging during this period will help reduce the work load during the critical flowering period.
- At flowering, important agronomic and morphological characteristics can be easily identified. This is the critical stage to prevent genetic contamination of the crop. For example in BH660 seed production, male parent grown in the female rows can be easily recognized by its purple color and should be removed quickly.





**Figure 12.** This amorphous plant in the field of BH660 certified seed production plot is an off type and should be removed before it starts flowering, shading pollen.

**For efficient rouging, consider the followings;**

- Limit the rouging team to 6 to 10 people including the supervisor for ease of operation.
- Before starting rouging provide, proper training on the identification and removal of contaminant plants.
- The team should start in a corner of the field and work through it slowly, walking parallel and in the same direction down the rows.
- Use large stakes to mark areas of the field that have been rouged.

**When to rouge**

- Before genetic or physical contamination occurs.
- During times favorable for visual identification.

### 1.6.11 Detasseling

Timely detasseling (removal of the male parent) in female rows in a maize hybrid seed production field is the most critical in genetically pure hybrid maize seed production.

It is important that all tassels from the female rows must be removed prior to shading pollen (Figure 13). The detasseling operation involves a physical removal of tassels by either manually or in combination with mechanical devices. There are other options to eliminate the pollen but we will not discuss these options in this manual.



**Figure 13. Clearly observed male rows and perfectly detasseled female rows. Nicking of female and male flowering results in good cob formation and seed setting.**



The following suggestions help to practice perfect detasseling:

- Tassels must be removed from all female plants before shedding and silk emergence.
- Fields must be worked daily, meaning 7-day workweeks, rain or shine.
- Beware of female plants that begin shading pollen before fully emerging from the leaves.
- The supervisor is responsible for recruiting, transporting, training, and managing the detassellers in his team.
- Tassels should be pulled out when they are well out of the boot. This often occurs 1 or 2 days after the tassels are first visible.

Make sure not to remove any leaf along with the tassel as this can significantly affect seed yield.

Removal of the flag leaf with the tassel greatly reduces the final seed yield of the hybrid. Study showed that, seed yield of BH660 decreased progressively and significantly from 40 to 32 q/ha with the removal of two or more leaves with the tassel ( Table 5).





**Figure 14. Detasseöling removal stages of male part from female parent**

Table 5. Effect of tassel and leaf removal on the seed yield of BH660.

Treatment	Seed yield (q/ha)	Percentage yield decrease
Tassel removal only	41.0a	-
Tassel + one leaf	40.5a	1.2
Tassel + two leaves	36.9b	10
Tassel + three leaves	35.1b	14.3
Tassel + four leaves	31.9c	22.1

Source: Bako Progress Report (1995 -1999).

- Tassels should not be left hanging on the maize plant because they may still be able to shed pollen.
- Make sure to remove tassels from tillers and suckers as they are often short and can be easily missed.
- A field which contains at any one inspection more than 0.1% of off type plants that have shed or are shedding pollen when 5% or more of the plants in the field have apparently receptive silks shall not be *certified*.

## Removal of pollen parent

The male row should be removed as soon as pollination is complete. In many instances in Ethiopia, the male rows are kept till they reach physiological maturity and are removed from the field at the time the female rows are harvested. This practice should be avoided as it can contribute to male- female mixtures. The maximum off type and pollen shading plants for different seed classes are listed below (Table 6).

Table 6: Maximum off type plants before flowering and pollen shading heads in seed parents at flowering

Category	Off type plants	Pollen shading heads
	Max %	Max %
Parental lines	0.1%	0.2%
Basic seed	0.1%	0.2%
Certified seed	0.1%	0.5%

Source Ethiopian standards, ES 420:2012

### 1.6.12 Harvesting

The female rows are harvested when they reach physiological maturity when 75% of kernels in central part reach a black layer.

Before starting harvesting;

- All kinds off-types must be removed and the field should be free of contaminants.
- Harvesting at the moisture content between 13-14% is useful in reducing the cost of drying and packaging of seed can be done directly from the field.

There are two methods of harvesting maize seed; machine harvesting and hand picking.

**Hand picking.** In hand picking, diseased cobs can be sorted out and discarded. The disadvantage is that it is time consuming.

**Machine harvesting** is faster than manually harvesting the cobs. The disadvantages are seed damage and harvesting of diseased cobs and spreading the disease to other seeds.

### **1.6.13. Post harvest management and seed processing techniques**

This includes drying, sorting, shelling, cleaning, treating and bagging and storage of seed before distribution.

#### **Drying**

Maize should attain the pre determined moisture content (13-14 %) is after being harvested and shelled. Field drying in the sun is commonly practiced. However, the seed should not be left in the field so long that it is at the risk of insect and disease damage.



### Sorting

Cobs are sorted to discard off-types, moldy damaged or doubtful and diseased ears etc. Sorting of the cobs can be done either at the farm or at the site of shelling.



**Figure 14. Sorting of hybrid maize cobs**



**Figure 15. Do not leave maize seeds in these kinds of plastic sacks in the sun for a long time**

### Shelling

The sorted ears are shelled when the moisture content of the seed reaches 13-14 %. Very low moisture contents may result in more seed damage during shelling. Shell seed with as little pounding can cause mechanical damage to seed coat those results in reduced germination and seedling vigor. Different types of maize shellers are available from which the producer can choose for his farm. There are also effective small-scale maize shellers designed in Ethiopia. It is important to use clean and dry (preferably cemented or plastic sheet)

threshing floor to avoid contamination by inert matter and absorption of moisture from the floor.

### **Cleaning and Grading**

Cleaning and size grading is aimed at removal of all inert matter including immature, shriveled, broken, light and undersized seeds, weed seeds, other crop seeds etc. from the seed. Grading machines are used to grade seeds in their shapes and sizes. The grading process is necessary especially if the seed is to be planted by precision machine planters.

### **Seed treatment**

Seed treatment is the process of coating seeds with suitable formulation of one or several chemical protectants in storage. Insecticides are applied to seeds to protect them against insect infestation in the field and the store. It is important to treat the seed with fungicide (thiram 125g/100kg) and insecticide before storage. The seed must be inspected regularly and fumigated when necessary to control insect pests such as weevils.

### **Seed packaging:**

Seed packaging is a means of ensuring safe delivery of a seed to end users, farmers. In tropical countries, special packaging materials are required as the hazards are more severe than those in the temperate countries. The reasons are:

- Seed may travel long distances by animal drawn carts or on donkey backs creating a lot of jolting and rubbing along the way,
- In addition the roads are very poor resulting in bouncing and vibration of seeds. This can harm the embryo of the seed. There is rapid re-infestation after fumigation due to favorable climatic conditions for their development. Continuous monitoring and fumigation or chemical treatment is required to keep insect infestation under control for a long time.
- In general, a seed producer in tropical countries such as Ethiopia requires advanced planning and preparation to overcome storage problems. For more information please refer to the section on storage pests and their control methods.

### **Tagging and Labeling**

Seeds are weighed and bagged in different sizes like 6.25, 12.5 and 25 kg as needed. Bagged seeds should be labeled with the necessary information using tags. The tags should be prepared in duplicate, so that one is put in the bag and the other is attached outside the bag.

The following information should be inscribed on the tag as indicated in the Ethiopian seed standards (ES 420: 2012).



- **Name of the producer,**
- **Name of certifying agency,**
- **Crop species,**
- **Name of the variety and class of seed,**
- **Germination percentage,**
- **Purity percentage,**
- **Year of production,**
- **Net weight in Kg,**
- **Batch or identification number,**
- **Moisture content in percentage.**

### **Storage**

Hybrid maize seed is stored for a number of reasons and for various length of time (before drying, before distribution and before planting in the farm). The main problems that contribute for deterioration of seed in the store are moisture and temperature. If the initial moisture content of the seed is above 13% for every one % increment of moisture the life time will be reduced by half and when the temperature increase by 5% the life time also decrease by half. Adequate storage facilities be in place for effectively maintaining and distributing the seed to farmers.



**Figure 16. Seed storage**

## **1.7 Quality assurance**

The success of farmer's maize crop depends on the quality of seed planted. Even good management cannot produce high yields from poor quality seed that is either contaminated by poor detasseling or other factors such as diseases and weed infestations. It is only when farmers obtain and plant seeds of high genetic purity and manage their fields properly can they get high yield and increase their total production.

Production of quality hybrid maize seed is the combined effort of many trained scientists and field technicians who grow, inspect, rogue, detassel, and care seed production fields throughout the growing season and harvest the crop when it attains physiological

maturity. Quality seed of hybrid maize seed is produced when genetically pure breeder seed, basic seed and certified seed is planted. Therefore, a hybrid maize seed producer should make sure that the basic seed he/she is buying is of high genetic purity and true to type. The availability of an internal seed testing laboratory is one of the wisest investments to improve quality standards.

### **1.7.1. Field inspection**

The standard set quality requirements like field inspection and laboratory seed tests and proper labeling ensure quality seed supply to seed buyer

- The inspector must first review the submitted application together with the supporting documents showing the proof of origin of the seed planted.
- The variety to be certified must have undergone national performance trial (NPT) and is officially released.
- The inspector should verify the seed source. In the case of hybrid maize, the basic seed should be produced by a licensed/authorized company.
- The field has to be inspected at least four to five times during the life cycle of the crop following the national standards for approval or rejection of the seed

#### **When to inspect**

- **During planting:** The main objective of this inspection is to determine the origin and genetic purity of the basic seed planted. It is also to make sure that there are no volunteer plants in the field and the isolation distances are correct.



- **During vegetative growth:** This inspection is to check if there are off type plants to be rouged out. It is also to make sure if the area surrounding the crop is kept clean.
- **Before flowering:** It is to check if silks and tassels have emerged and off type and diseased plants are eliminated.
- **After harvest:** At harvest moisture content should be 11%. Conduct seed germination tests. Germination percentage less than 85% is not acceptable.

### 1.7.2. Seed testing (laboratory standard)

Seed producers must be aware that classes of seeds produced fulfill the following national minimum quality standard (Table 7) to legally marketing or distribute Hybrid seed to consumers

Table 7: Laboratory standard for hybrid maize seed

Category	Parental lines	Basic seed	Certified seed
Pure seed (min %)	99	99	98
Other crop seed (max %)	N.S	0.2	0.3
Weed seed (max %)	N.S	0.2	0.3
Infected/infested seeds (max %)	N.S	0.02	0.05
Inert matter (max %)	0.5	1	2
Germination (min %)	90	85	85
Moisture content (max %)	13	13	13

Source: Ethiopian standards, ES 420: 2012

### Bibliography

Christopher R Dowswell, R.L Paliwal and Ronald P. Cantrell. 1996. Maize in the third world. Westview press, Inc

Crop management research training. Egerton University, Kenya CIMMYT seed week 1993

Wolde, Legese et al 2012. Maize breeding manual, Ethiopian Institute of Agricultural Research, Addis Ababa, Ethiopia

Joginder Singh. 1987. Maize seed production and certification. All India Co-ordinated Maize Improvement Project, Indian Agricultural Research Institute, New Delhi, India.

Joginder Singh. 1987. Field manual of maize breeding procedures. Indian Agricultural Research Institute, New Delhi, India.

Kling JG, Edmeades G. 1997. Morphology and growth of maize. IITA/CIMMYT Research Guide 9. Training program, International Institute of Tropical Agriculture (IITA), Ibadan, Nigeria 36pp. 2<sup>nd</sup> edition.

MacRobert, J.F. 2009. Seed business management in Africa. Harare, Zimbabwe, CIMMYT.

Maize seed production manual. Technical workshop. Harare, 15-24 February 1999. International Maize and Wheat Improvement Center (CIMMYT)

National Maize Research Project. 2010. Maize breeding and hybrid seed Production Manual.

Worku, M, Twumasi-Afriye, Wolde, L., Tadesse, B., Demisie, G., Bogale, G., Wegary, D., and Prasanna, B.M. (Eds) 2012. Meeting the challenges of global climatic change and food security through Innovative maize research. Proceedings of the Third National Maize Workshop of Ethiopia, EIAR and CIMMYT, Addis Ababa, Ethiopia.

## Section 2

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### Major Field Insect Pests of Maize and their Management

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#### 2.1. Introduction

Insect pests are among the major problems that limit the productivity of maize in Ethiopia. The average grain yield losses due to insect pests are estimated to range from 20-50% and under severe condition 100% crop failure is not uncommon. There are numerous insect pests attacking maize in the field, but relatively a few species are economically important on the plant from seedling to maturity. Some of these insect pests and their suggested management options are given in this section.

#### 2.2. Seedling pests

##### 2.2.1. Cutworms (*Agrotis ipsilon* (Hufnagel))

There are different species of cutworms attacking maize seedlings. However, the most common species attacking maize in Ethiopia at the seedling stage is *Agrotis ipsilon*. It is very common in middle altitude areas of Ethiopia such as Bako, Hawassa, Arsi-Negele, etc.



**Nature of damage:** Larvae of cutworms cut maize seedlings at or a little below ground level, make small holes along the initial leaves, or remove sections from the leaf margins. On older plants large cutworms feed on the stems just below the surface, leaving cavities that cause the plants to wilt and eventually die. Most cutworm feedings take place at night. Some may occur during the day, but cutworms generally remain sheltered below the ground during day time,

**Description and life cycle:** Removal of the soil around the cut or injured seedlings or older plants will expose two or three young, small cutworms of 0.5 to 1.0 cm in length or a single, oily or greasy large (4 - 5 cm long), grayish, brownish, or black worm. The larvae curve their bodies into a C" shape and remain motionless for a short period when disturbed (Fig. 1). After molting for six times, they develop into brown pupae in cells prepared by the larvae a few centimeters below the soil surface. The adults are 2 to 3 cm long and dull brown, gray, or black with markings on the front wings. The wing markings of the adults, which are strong fliers, vary according to the species. Females deposit their eggs on plant stems or on the surface of moist soil. Depending on the location, one to three or four generation may occur in a year.



**Figure 1. Adult moth (left) and a cutworm and a damaged maize plant (right)**

### **Control options**

- Early land preparation and good weed control will help to reduce cutworms.
- Fields should be cultivated at least two weeks before planting.
- Scout fields and use rescue treatments as a primary cutworm control strategy.
- It is advised that in case of heavy cutworm infestation pre-plant or planting time application of soil insecticides to prevent damage and rescue treatment after infestation appears.
- Insecticide application should be followed by shallow cultivation to mix soil and get the insecticide below-ground cutworms. Insecticide treatment is most effective when soil is wet. Soil insecticides can also control important soil insect pests of maize at seedling stages such as white grubs and wireworms.
- Apply beneficial nematodes when the cutworms first appear.
- Keep field free of weeds during the off-season

Different species of stem borers and termites also cause damage to maize at seedling stage, but they rarely cause economic losses at this

stage. If they happen to become major pests, some of the control measures mentioned at the different developmental stage of the crop can be applied.

### **2.2.2. Armyworms (*Spodoptera exempta*)**

Though there are different species of armyworms causing damage to maize, the commonest species is what is known as the African armyworm, *Spodoptera exempta*, which is a sporadic pest occurring every 2-3 years in an outbreak form in Ethiopia and nearby countries such as Kenya, Tanzania and Uganda.

**Nature of damage:** Extensive leaf damage, which becomes quite noticeable as the leaves unfold is caused by the small, dark-green worms. Upon hatching they begin to feed by scraping the leaf epidermis later migrate to the whorl, where they feed voraciously. Late infestation of the whorl damages the tassel and all the ear parts in a manner similar to that of the corn earworm. In hot, dry weather, fully grown larvae that have dropped to the ground before pupation will begin to feed at the base of the plant, cutting the tender stalk (Figure 2).

**Description and life cycle:** Usually, only one fully-grown armyworm is found in the whorl, since at the second or third larval instar it starts to show cannibalistic tendencies. After six larval instars, the full-grown (3 cm-long), grayish brown worm drops to the ground and pupates in an earthen cell a few centimeters below the soil surface. The adults, dark-gray moths, 20 to 25 mm long with a conspicuous



white spot on the extreme tip of the hind wings, lay fuzz covered clusters of a few to several hundreds, white, pinkish, or light-green eggs usually on the underside of leaves. Larvae emerge from the eggs simultaneously, at which point their mortality rate extremely high as a result of factors such as rain, predators, and parasitoids.

### Control options

- Different organo-phosphahate (endosulfan, malthion, fentrothion, etc.) and carbamate (carbaryl) are recommended for use when there is an outbreak.
- Biological control mainly using entomo-pathogens - e.g. *Beauveria bassiana*, *Metarrhizium anisopliae*, and *Bacillus thuringiensis*
- Forecasting the occurrence of the outbreak using different types of traps such as light and pheromone traps



Figure 2. Armyworm larva feeding on maize plant (left) and the adult moth on leaf (right)

## **2.3. Sap suckers and disease vectors**

### **2.3.1. Maize streak virus vector leafhoppers (*Cicaduina* spp.)**

Maize streak virus and its leafhopper vectors are common in Gambella area in particular and western Ethiopia in general, though they can be found in other parts of Ethiopia as well.

**Nature of damage:** This insect does not cause economically significant damage through its feeding, but transmits the maize streak virus (MSV) (harbored by several wild and cultivated graminaceous plants), which itself can cause severe injury to maize. The initial symptoms of the disease are small, whitish spots, which become colorless streaks running parallel to the veins along the entire length of the leaf. When the plant is infected at the seedling stage, this streaking appears on all except the lowest leaves. Moreover, the plants become stunted and, though they produce later, the plant will produce smaller than normal ears (Figure 3).



**Figure 3. Adult leafhoppers (left) and the maize streak virus disease (right)**

**Description and life cycle:** Either nymphs or adults may be found feeding and resting in leaf whorls can transmit the maize streak virus. The leafhopper is straw yellow and 3 mm long and has a pair of black dots between its eyes.

## **Control options**

### **Cultural control**

Cicaduina populations generally increase in irrigated cereals and grasslands or in wild grasses during rainy seasons. They disperse away from these areas when the host plants dry out and become unfavorable. Thus, control can be achieved by planting maize well away from previously irrigated cereals or grassland; in particular, planting downwind of such areas should be avoided. Staggered planting of crops will favor multiplication of the vector and increase the risk of maize streak virus infection in the later plantings; thus, planting synchronously over a wide area is recommended. A barrier of 10 m of bare ground between maize fields and previously infested



crops can reduce MSV incidence, by inhibiting trivial movement of leafhoppers. Removal of remnants of cereal crops serving as infection sources will assist control. Removal of MSV-infected maize plants (rouging and burying or burning) at an early stage is also beneficial.

### **Host-plant resistance**

There are many resistant maize hybrid varieties that have been developed. However, they yield poorly compared with existing local susceptible varieties under certain conditions, or have other undesirable qualities. Cross-pollination with other varieties leads to breakdown of MSV resistance, so it is important to use certified seed at each planting. Gambella Composite variety coupled with some insecticides such as Endosulfan provide effective control of the vectors.

### **2.3.2. Maize aphid (*Rhopalosiphum maidis* (Fitch))**

This insect is distributed throughout maize growing areas of the country.

**Nature of damage:** The role of this insect as a vector of the sugarcane mosaic virus, maize dwarf-mosaic virus, and maize leaf-fleck virus makes it a pest of considerable economic importance. Diseased plants

may become stunted, show a conspicuous yellowish mottling, and turn reddish as they mature. Young plants that have been infected seldom produce ears. Piercing of the leaves and sucking of plants fluids by the insect causes some yellowish mottling, but this damage is seldom of economic importance. Sugary droplets excreted by the aphids favor the development of black molds and make the plants sticky. These insects usually attack maize plants at the end of the mid-whorl stage. Their colonies may completely cover emerging tassels and the surrounding leaves, preventing pollen release. In severe outbreaks the ear shoot is also infested and seed set may be affected.

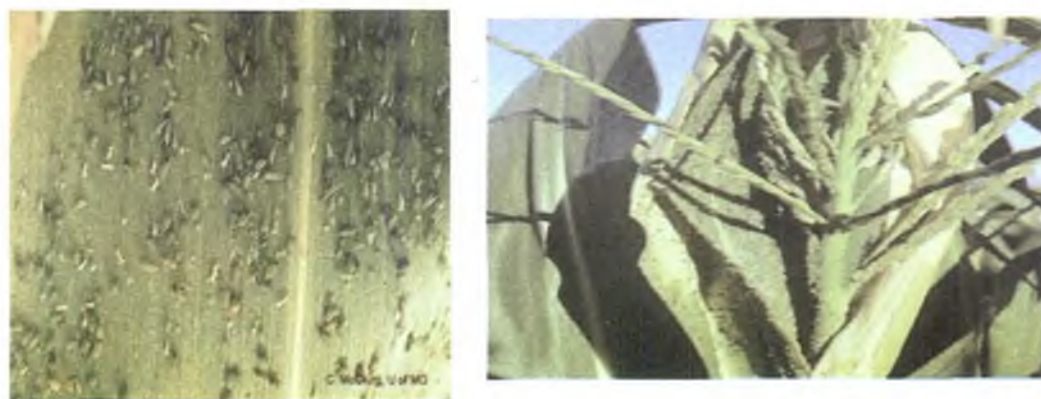
**Description and life cycle:** The small, greenish blue adult females do not lay eggs but give birth to living nymphs. In crowded colonies winged forms are produced that eventually migrate to other plant. Skins that have been shed give the colonies a whitish appearance (Figure 4).

### **Control option**

Maize leaf aphid control is most effective 2 to 3 weeks prior to tasseling. It is rarely advisable after this period. During this period if the number of aphid per plant reach 15 apply Chlorpyrifos or malathion at the rate of 2 lt/ha particularly in the highlands. Maize

grown in lowland and intermediate elevations are rarely damaged by aphids as the parasitism rates are very high.

Although control is not normally required once the tassels have emerged, on occasion aphids may interfere with pollination and treatment may be required during pollen shed. If greater than 50% of the tassels are covered with aphids and their honeydew prior to 50% completion of pollination and the plants are under stress, treatment may be needed if the amount of pollen being shed is insufficient for good pollination. If control is a must, the same insecticide at the same rate indicated above can be used.



**Figure 4. Colonies of corn aphids on maize leaves and stems**

## **2.4. Pests of root, stem, ear and tassel**

### **2.4.1. Stem borers**

This pest occurs in all maize growing areas of Ethiopia.



### **Spotted stem borer (*Chilo partellus* (Swinhoe))**

**Nature of damage:** The initial symptom of infestation on young plants is rows of oval perforations in leaves of the unfolding whorl. This damage is caused by the feeding of the young larvae. As they develop, the larvae tunnel into the leaf midribs, damage the growing point {causing a condition referred to as "dead heart"}, and bore into the stem.

**Description and life cycle:** The young stem borers are small, spotted, and yellowish. When fully grown they are 20 to 25 mm long and spotted, with colored stripes along the back of the body. Before developing into pupae, the larvae prepare an exit for the adult by leaving intact at the end of their tunnels only the thin exterior wall of the stem, which reach about 15 mm long, deposit white, scale-like eggs in overlapping rows, usually on the underside of leaves ( Fig. 5).

### **Control options**

#### **Cultural practices**

Intercropping maize with non-hosts crops like cassava or legumes like cowpea can reduce spotted stem borer damage. Alternatively, maize can be intercropped with a repellent plant such as silver leaf desmodium (*Desmodium uncinatum*) and a trap plant, such as Napier

grass (*Pennisetum purpureum*), molasses grass (*Melinis minutiflora*) as a border crop around this intercrop to protect maize from stem borers. The trap plant draws the adult female away from the crop. More eggs are laid on the trap plant than on the crop but the larvae develop poorly or not at all on the trap plant. This practice is known as "push-pull" strategy.

Good crop hygiene through the destruction of maize residues by burning to get rid of the larvae and pupae within the stems, and removal of volunteer crop plants and/or alternative hosts, prevents carry-over populations. This helps in limiting the initial establishment of stem borers that would infest the next crop. Moreover, early slashing of maize stubble and laying it out on the ground where the sun's heat destroys the larvae and pupae within can reduce future infestations. Early sowing as soon as the rain starts can offset the damage caused by stem borers in general.

### **Biological control**

Biological control by two parasitic wasps, *Cotesia flavipes* and *Xanthopimpla stemmator*, that attack the spotted stem borer, has shown good results. *Cotesia flavipes* locates the stem borers while they are feeding inside the plant stems. The wasp lays about 40 eggs into a stem borer. Upon hatching the larvae of the parasitic wasp feed internally in the stem borer, and then exits and spin cocoons. *Xanthopimpla stemmator* operates similarly but attacks the pupae.

Habitat management practices that conserve these parasitoids and predators like ants and earwigs can help in the control of the spotted stem borer.

### Chemical control

Diazinon 60% (1-2 l/ha), Endosulfan 35% (2-2.5 l/ha), carbaryl (1.28 kg a. i/ha.), cypermethrin (16 ml a. i/ha) and carbofuran 1.5 kg a. i/ha) are recommended. Chemical control can be achieved by applications of granules or dusts to the leaf whorl early in crop growth to kill early larval instars. This method has limited effectiveness once the larvae bore into the stem. Neem products (powder from ground neem seeds) are reportedly effective and may be applied to the leaf whorl in a 1:1 mixture with dry clay or sawdust.



Figure 5. Life cycle and damaging symptoms of the spotted stem borer



### **Maize stem borer (*Busseola fusca* {Fuller})**

This insect is regarded as the most important pest of maize in sub-Saharan Africa including Ethiopia.

**Nature of damage:** The larvae feed very little or not at all where the eggs have been laid but migrate into the leaf whorl, where they begin scraping the tender leaves. As they unfold, the leaves show perforations. Deep feeding in the whorl destroys the growing point, causing a symptom referred to as "dead heart". Medium sized larvae migrate down the stem, bore into it, and as they do so expel a dust from the interior. Second generation larvae, like those of other species, feed on tassels, ear shanks, ears, and stem and may there enter a period of dormancy and become non-pigmented.

**Description and life cycle:** The full-grown borer is about 3 cm long and has a pinkish body with a brown head. It prepares an exit for the adult {a dark- brown moth} by leaving intact the thin outer wall of the stem, which serves as a lid for the round exit. The moths deposit their nearly spherical, light-yellowish eggs between the stem and lower leaf sheaths, as do the adults of the African pink borer (Fig. 6).

## Control options

### Cultural practices

Intercropping maize with non-host crops like cassava or legumes like cowpea can reduce spotted stem borer damage. Alternatively, maize can be intercropped with a repellent plant such as silver leaf desmodium (*Desmodium uncinatum*) and a trap plant, such as Napier grass (*Pennisetum purpureum*), molasses grass (*Melinis minutiflora*) as a border crop around this intercrop to protect maize from stem borers. The trap plant draws the adult female away from the crop. More eggs are laid on the trap plant than on the crop but the larvae develop poorly or not at all on the trap plant. This practice is known as "push-pull".

Good crop hygiene through the destruction of maize residues by burning to get rid of the larvae and pupae within the stems, and removal of volunteer crop plants and/or alternative hosts, prevents carry-over populations. This helps in limiting the initial establishment of stem borers that would infest the next crop. Early slashing of maize stubble and laying it out on the ground where the sun's heat destroys the larvae and pupae within can also be utilised. Early sowing as soon as the rain starts can offset the damage caused by stem borers in general

### **Biological control**

Biological control by two parasitic wasps, *Cotesia flavipes* and *Xanthopimpla stemmator*, that attack the spotted stem borer, has shown good results. *Cotesia flavipes* locates the stem borers while they are feeding inside the plant stems. The wasp lays about 40 eggs into a stem borer. Upon hatching the larvae of the parasitic wasp feed internally in the stem borer, and then exits and spin cocoons. *Xanthopimpla stemmator* operates similarly but attacks the pupae. Habitat management practices that conserve these parasitoids and predators like ants and earwigs can help in the control of the spotted stem borer.

### **Chemical control**

Diazinon 60% (1-2 l/ha), Endosulfan 35% (2-2.5 l/ha), carbaryl (1.28 kg a. i/ha.), cypermethrin (16 ml a. i/ha) and carbofuran 1.5 kg a. i/ha) are recommended. Chemical control can be achieved by applications of granules or dusts to the leaf whorl early in crop growth to kill early larval instars. This method has limited effectiveness once the larvae bore into the stem. Neem products (powder from ground neem seeds) are reportedly effective and may be applied to the leaf whorl in a 1:1 mixture with dry clay or sawdust.



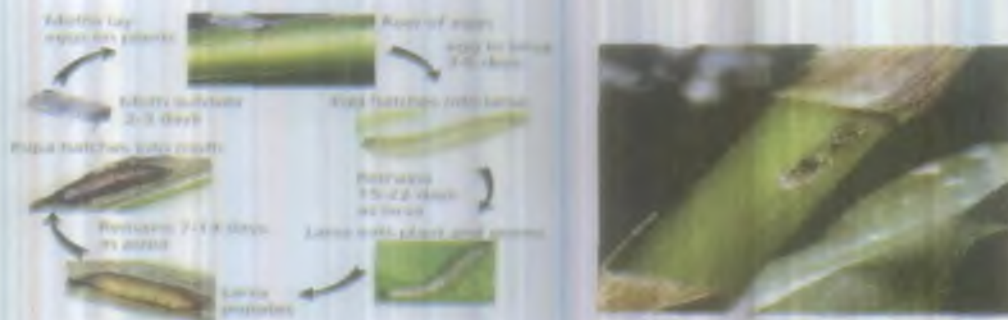


Figure 6. Life cycle and damage symptom of the maize stem borer

#### 2.4.2. African bollworm (*Helicoverpa armigera* (Hubner))

The African bollworm (ABW) can clearly be classified as a general pest since it has so many different host plants, but its method of attack tends to be peculiar to the crop in question. It has many common names, including "American bollworm" (a misnomer as it is an African pest), tobacco budworm, maize earworm and tomato fruit worm. It is widely distributed in Ethiopia.

**Nature of damage:** The feeding hole is clean and usually circular. One larva may damage several plants. After eating the silks on developing cobs, it sometimes feed on the soft seeds at the tip of the cob. It is sporadically important on maize (Figure 6).



**Figure 7. ABW on young maize cob (left) and its entry point into maize cob (right)**

**Description and life cycle:** The adult is brown, stout bodied and mainly nocturnal (Figure 8.). Eggs are tiny (about 0.5 mm), spherical and white when freshly laid but soon turn brownish. The early instars feed within silk and later instars feed on the developing cob. They habitually leave part of the body exposed during feeding. The mature larva is stout and about 4 cm long. It has four pro-legs and varies in colour between yellowish green, green, brown and black with a characteristic longitudinal marking of pale band, a brown to black band and another pale band on each side of the body. Pupation occurs in the soil.



**Figure 8. Life cycle of ABW**

**Control options**

Chemicals such as endosulfan and carbaryl are recommended to use against early larval instars. Moreover, different strains of Bt such as Bti are recommended as bio-pesticide against the African bollworm. The egg parasitoids, *Trichogramma* spp. are also recommended against the pest.



### **2.4.3. Termites (Microtermes spp., Macrotermes spp. and Odontotermes spp.)**

Termites occur in sub-Saharan Africa, especially the savanna and semiarid, and India. In Ethiopia it is a big menace to maize production particularly in western Ethiopia.

**Nature of damage:** Termites occasionally cause partial or total defoliation of maize seedling but are principally damaging to maturing or mature plants (Figure 9). After about three months of plant growth, termites begin to attack the main root system, prop roots, and stems and eventually pack the stems with soil and cover them with galleries or tunnels made of thin sheets of soil. As plants mature the amount of damage increases rapidly and so does the likelihood of lodging, brought about directly by termites. The longer a field has been cultivated, the greater will be the yield losses caused by these insects.

**Description and the life cycle:** these soft-bodied insects, often referred to as "white ants", occur in various forms. The sexual forms, the queen and her cohort, have four wings extending beyond the abdomen, which are lost after pairing. Once the queen is established in a nest, her abdomen becomes enlarged, and she produces thousands of eggs, from which nymphs emerge. These either become soldiers, which protect the termite colony, or workers, whose

function is to feed members of the colony. Both of those forms are sterile.

### **Control options**

Use an integrated program to manage termites. Combine methods such as modifying habitats, excluding termites from building nests by physical and chemical means, and using mechanical and chemical methods to destroy existing colonies. Early harvesting, use of lodging resistant varieties and seed dressing chemicals among others are also used for termite control.



**Figure 9. Termites (left) and termite damaged maize plants (right)**

**(Source: [en.wikibooks.org](http://en.wikibooks.org) (left) and [keyslucidcentral.org](http://keyslucidcentral.org) (right))**

## Bibliography

- Abraham Tadesse, Ferdu Aszerefegne, Assefa G/ Amlak and Adhanom Negassi. 1992. Research highlights on maize insect pests and their management in Ethiopia. Pp. 34-42. In: Benti Tolesa and J. K. Ransom (eds.). Proceedings of the Second National Maize Workshop of Ethiopia, 5-7 May 1992. Addis Ababa, IAR and CIMMYT, Addis Ababa, Ethiopia.
- Adhanom Negassi and Abraham Tadesse. 1985. A review of research on insect pests of maize and sorghum in Ethiopia. Pp. 7-19. In: Tsegede Abate (ed.), a review of crop protection research in Ethiopia. Proceedings of the First Ethiopian Crop Protection Symposium. IAR, Addis Ababa.
- Emana G. AbrahamTadesse, Mulugeta Negeri and Tadele Tefera, Hadush Tsehaye and Asmare Dejene. 2008. Review of entomological research on maize, sorghum and millet. pp. 167-244. In: Abraham T. (ed.). Increasing crop production through improved plant protection Volume I. PPSE and EIAR, Addis Ababa.
- Girma Demisse, Solomon Admasu, Emanu Getu and Ferdu Aszerefegne. Review of the past decades (2001-2011) research on pre-harvest pests of maize in Ethiopia. Pp. 166-173. In: Mosisa Worku, S. Twumasi-Afriye, Legesse Wolde, Berhanu Tadesse, Girma Demisse, Gezahegn Bogale, Dagne Wogary and B.M/Prasanna (eds.). Meeting the challenges of global climate change and food security through innovative maize research. Proceedings of the Third National Maize Workshop of Ethiopia, April 18-20, 2011, Addis Ababa. EIAR and CIMMYT, Addis Ababa Ethiopia.



## Section 3

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### Diseases of Maize and their Management

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#### 3.1. Introduction

There are different diseases of maize caused by fungi, bacteria and viruses that severely constrain maize production. The most common ones are caused by fungi. The different diseases can be further grouped into seed rots and seedling diseases, foliage diseases, stalk rots, ear and kernel rots. Each of these diseases occurs every year with varying degrees of severity. Problems with germination and stand establishment are related to seed decay, damping-off and seedling blights that are often encountered in the field at early stage of crop development. Others may occur at the middle and even at crop maturity stage causing leaf spots or leaf blights, wilts or premature death of plants ultimately leading to significant losses in quantity and quality. The extent of damage and loss caused by diseases in a given season depends on a number of factors including the susceptibility of the variety, the level of pathogen inoculum present and the environmental conditions during the season. It is important to identify each disease correctly in order to take appropriate management measures. In the following sections, most

important diseases and their management options are briefly described.

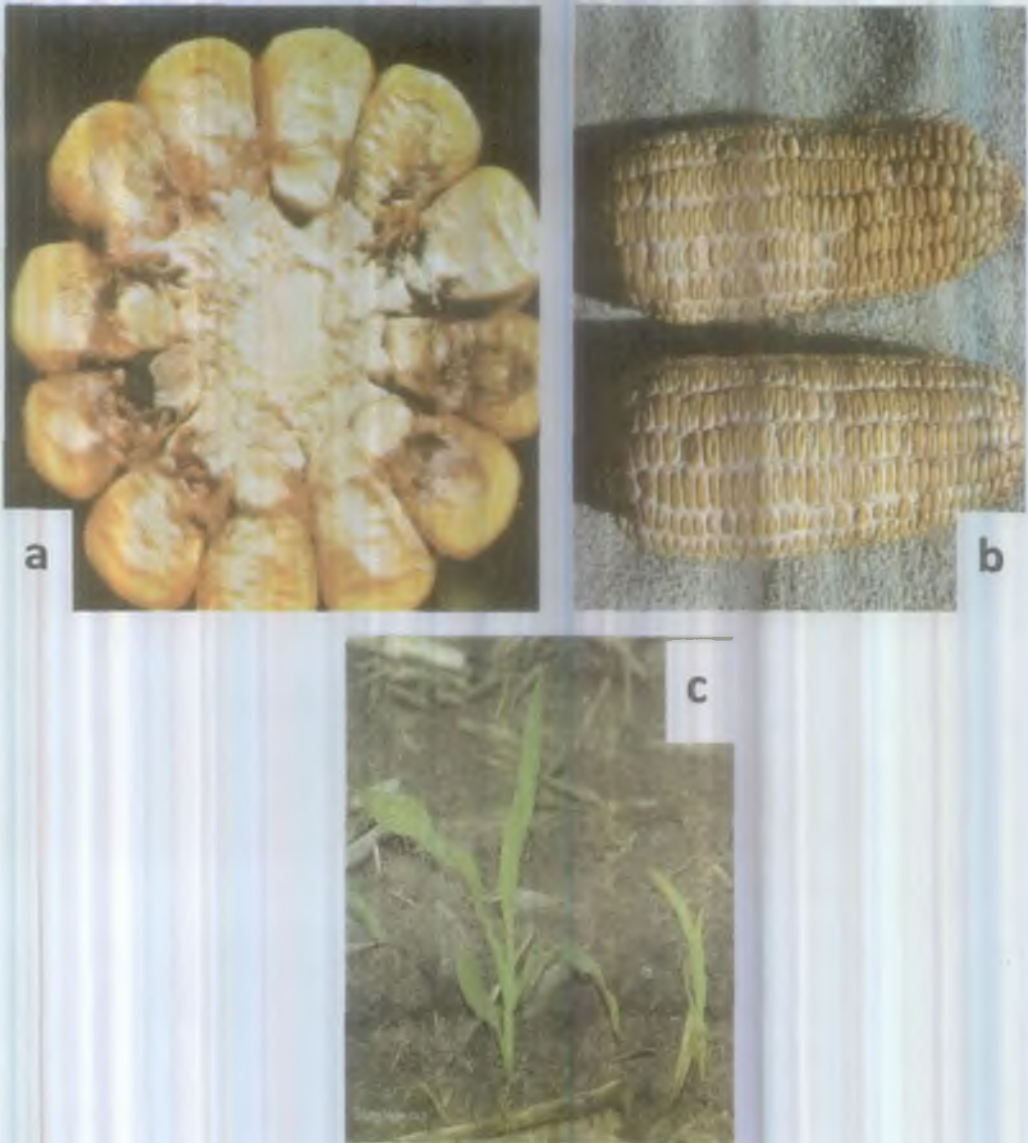
## **3.2. Fungal diseases**

### **3.2.1. Seed rot and seedling diseases**

Seed rot refers to rotting of seed before germination while seedling diseases include damping-off and seedling blight that any damage seed after germination leading to plant death. Severe infection may kill the embryo before germination (seed rot) or destroy the seedling before and after emergence. These complex diseases are caused by various fungal species individually or in groups.

#### **Seed rot diseases**

**Causal agents:** Seed rot is mostly caused by *Fusarium* spp., *Pythium* spp., *Diplodia* spp., and *Penicillium oxalicum* ( Fig.1 and Fig.2)



**Fig.1. Seed rot caused by *Fusarium* spp. (a) Fungal growth at the base of the seed, (b) on the cob due to high moisture and inappropriate storage after harvest. Fungal growth usually increases with less ventilation and high moisture in maize, and (c) maize seedling showing symptom on the upper part (right) and healthy seedling (left).**



**Symptoms:** Seeds may possibly rot before or shortly after germination that could result in low seedling emergence, or may emerge and later turn to yellow. These seedlings soon wilt that reduce plant population. This is aggravated by poor soil drainage, severely compacted soils, deep planting and use of poor quality seed.



**Figure 2. Seed rots caused by *Penicillium* spp. where each seed is severely infected by the fungus showing black discoloration.**

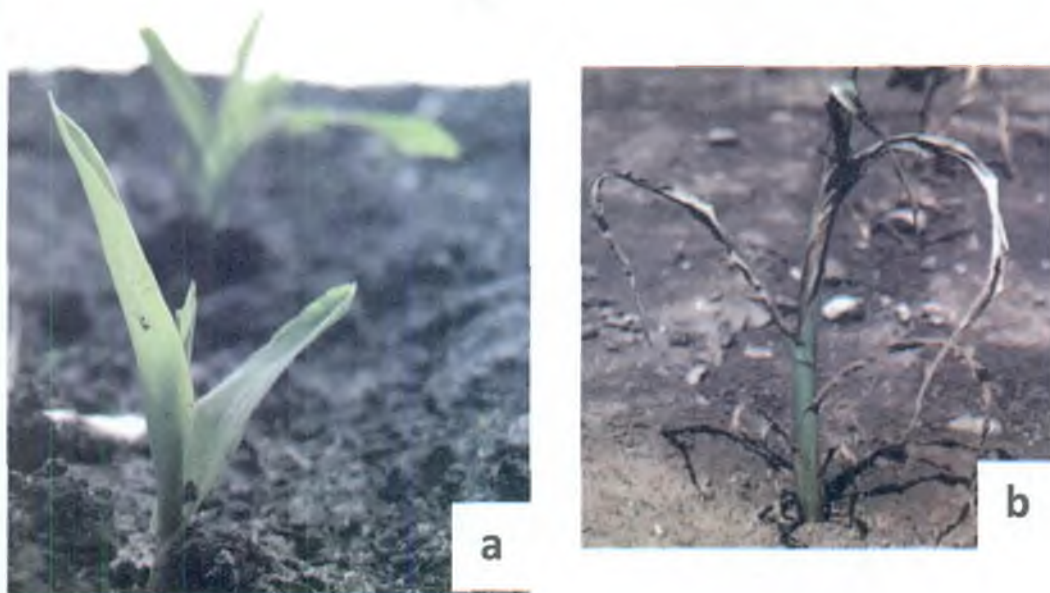
**Management:** Seed of high quality with high germination percentage should be planted. Seed treatment with appropriate fungicides reduces the risk of seed rot and seedling blight. Auspiciously, most maize seeds are sold pre-treated with fungicides at present. Fungicides registered for seed treatment that could be used for maize

include Thiram (80% WP), Granuflo (80% WP), Imidalm T 450 WS, and Noble 25% WP. In addition, good cultural practices and seedbed preparation reduce the risk.

### **Seedling diseases**

**Causal agents:** Damping-off and seedling blight are caused by *Fusarium* spp., *Bipolaris* sp., *Pythium* spp., and *Penicillium oxalicum* (Fig.3)

**Symptoms:** Soft rot of stem tissues near the ground level and water-soaking of seedling tissues. The rotted area may be dark, with sporangia in case of *Pythium*, white gray in case of *Diplodia*, white to pink in case of *Fusarium*, and bluish in case of *Penicillium*. *Penicillium* also causes necrosis on the tip of leaves, which later becomes brittle then seedlings soon die. Similarly, these diseases are aggravated by poor soil drainage, severely compacted soils, deep planting, and use of poor quality seed.



**Figure 3. Seedling diseases of maize. (a) Typical symptoms of infected young plant at early stage of crop growth; and (b) characteristic symptoms of young plant infected by *Phoma* sp.**

**Disease cycle:** Infected or contaminated seeds are major sources of seedling diseases through also soil contamination. Root and shoot infection of germinating and emerging maize seedling occurs by inoculums originated directly from the seed itself or from infested soil. Secondary spread could be by rain splash, wind, farm implements or man during farm operation.

**Management:** Seed of high quality with high germination percentage should be planted. Seed treatment with appropriate fungicides reduces the risk of seed rot and seedling blight. Auspiciously, most maize seeds are sold pre-treated with fungicides at present. Fungicides registered for seed treatment that could be used for maize



include Thiram (80% WP), Granuflo 80% WP, Imidalm T 450 WS, and Noble 25% WP. In addition, good cultural practices and seedbed preparation reduce the risk.

### 3.2.2. Common leaf diseases

#### **Turcicum leaf blight**

**Causal agent:** *Turcicum* leaf blight in maize is caused by a fungus called *Exserohilum turcicum* (Telomorph = *Setosphaeria turcica*) (Figure 4).

**Symptoms:** Large elliptic water soaked lesions on leaves appear that soon turn straw to dark brown color lesions on leaves.



**Figure 4.** Symptom of turcicum leaf blight caused by *Exserohilum turcicum* on maize leaf.

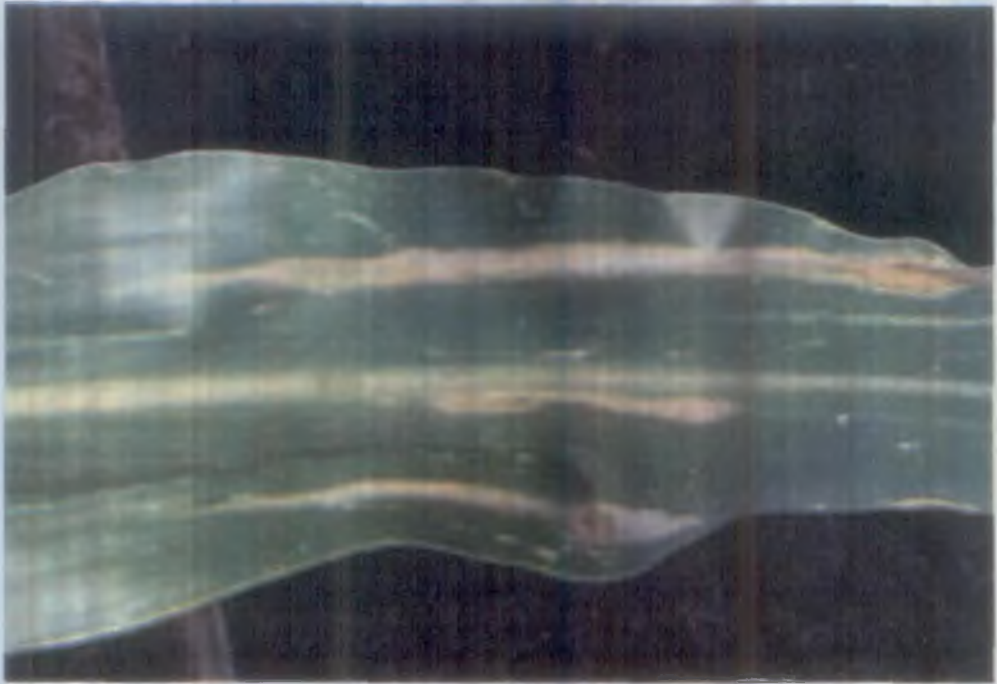
**Disease cycle:** The pathogen survives on/in infected leaves, husks, and other plant parts. Spores usually develop when weather conditions become conducive on these crop residues. These spores initiate disease in new crop and may move a long distance by wind. Secondary spread of the disease within and between fields occurs by conidia produced from lesions. The lesions are often rectangular. Disease development is favored by moderate temperature (18 - 27°C) and heavy dews during crop season.

**Control measures:** Choose maize varieties with good level of resistance. Use crop rotation with non-cereals and deep tillage to bury the residue and any crop refuses. Fungicides may be applied for seed crops starting when lesions appear.

### **Gray leaf spot**

**Causal agent:** Gray leaf spot of maize is caused by *Cercospora zeae-maydis*(Fig.5.)

**Symptoms:** This disease occurs in warm to hot areas of Ethiopia especially in humid seasons. Lesions are pale brown or gray to tan, long, narrow and rectangular, characteristically restricted by the veins. Losses have been severe in some maize growing areas in recent years. The fungus survives in maize residues. Very high humidity favors gray leaf spot development.



**Figure 5.** Gray leaf spot caused by *Cercospora zeae-maydis*.

**Disease cycle:** The pathogen survives on infected plant parts while spores develop when weather conditions turn conducive on these crop residues. These spores initiate new disease in maize crops. Spores may move a long distance by wind. Secondary spread of the disease within and between fields occurs by conidia produced from lesions.

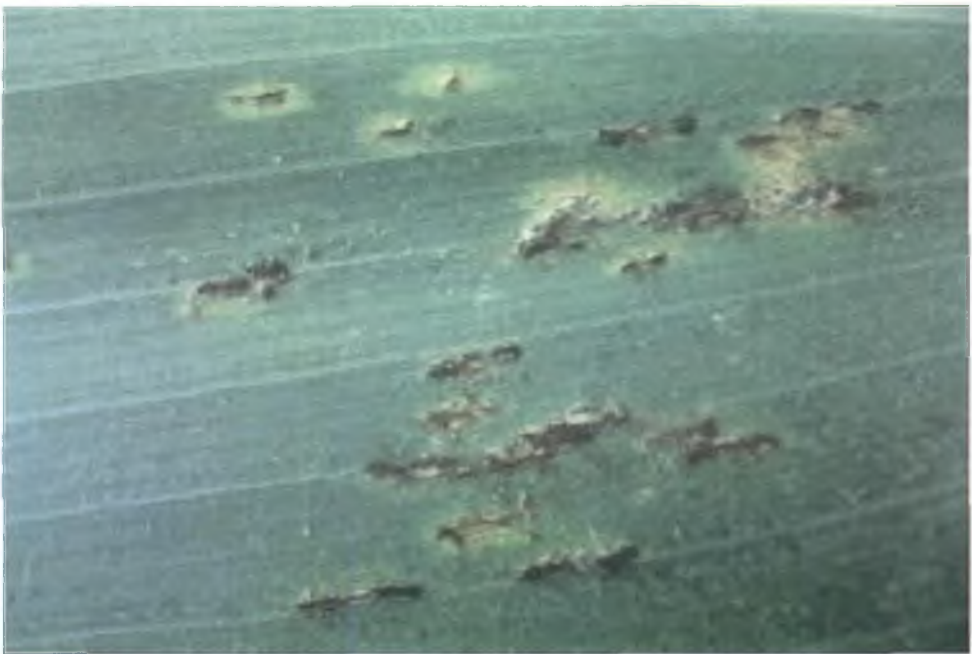
**Control measures:** Variation exists in hybrid maize for resistance, thus choose good level of resistant/tolerant variety. Destruct residue by fire or tillage and use crop rotation with non-cereal crop. Fungicide protection may be warranted for high value fields under severe disease pressure.



### **Common rust**

**Causal agent:** Common rust of maize is caused by a fungus named *Puccinia sorghi* ( Fig 6)

**Symptoms:** Red eruptions (pustules) occur on leaf surface. Each pustule contains thousands of rust spores that disperse by wind to cause new infection.



**Figure 6. Sign of common rust or pustules developed on maize leaf. Matured pustules contain large number of spores that are capable of infecting healthy maize plant in new crops**

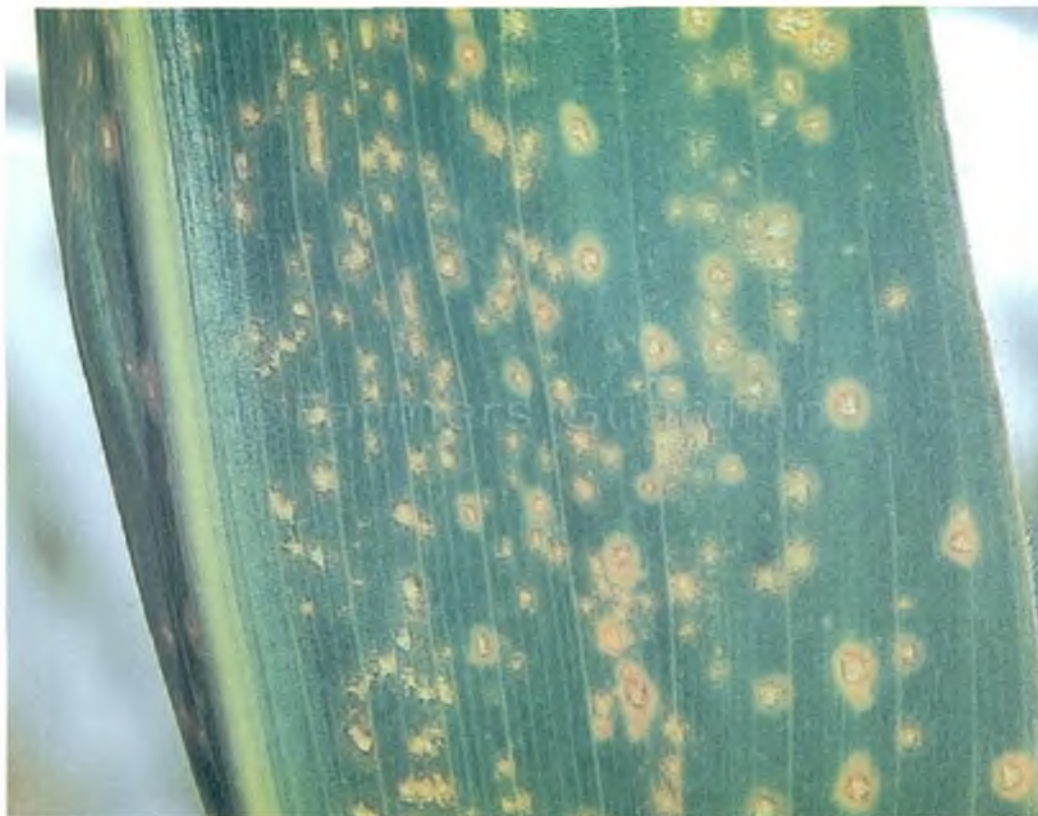
**Disease cycle:** The fungus survives on volunteer plants, or may come from other geographic zones by wind, on alternate host namely *Oxalis* spp. which is commonly found weed species.

**Control measures:** Maize varieties vary in resistance and thus choose variety with good level of resistance. Rust becomes serious rarely and thus may not need additional control measures. In case of high risk, fungicide can be applied only on seed crop considering the economics. Application will be effective only when it is applied at the beginning of the disease (when few pustules per leaf occur).

### **Eyespot of maize**

**Causal agent:** Eyespot in maize is caused by a fungus called *Kabatiella zea* (Fig.7)

**Symptoms:** Very small spots with 1 to 4 mm length that are translucent circular to oval spots with yellow halos appear. Initial spots are water-soaked; later develop to brown or purple border.



**Figure 7. Characteristic symptoms of eyespot disease on maize leaf.**

**Disease cycle:** The fungus overwinters on and in crop residues, seeds, and to some extent in the soil. When weather becomes favorable conidia are produced and infect maize seedling. Secondary spread is carried out by splashing of these conidia. Cool and humid weather favors disease development.

**Control measures:** Reducing the inoculum of this fungus is the primary target in managing this disease. Thus, crop rotation with non-cereals, tillage to bury the residue, and burning of any maize refuse are effective against this disease. These and integrating with



the use of resistant/tolerant varieties increase the level of efficiency in controlling the disease.

**Phaeosphaeria leaf spot**

**Causal agent:** Leaf spot of maize caused by *Phaeosphaeria maydis* (Figure 8).

**Symptoms:** Lesions are initially small, pale green or chlorotic, becoming bleached or dried with brownish margins. Spots are round, elongate to oblong that are scattered over the leaf. Black fruiting bodies of the fungus namely Pycnidia or Perithecia develop on lesions.



**Figure 8. Typical symptoms of Phaeosphaeria leaf spot on maize leaf.**

**Disease cycle:** The fungus persists in diseased plant parts in the field. Under favorable conditions, spores germinate and infect maize leaves. High rainfall and humidity favor disease development.

**Control measures:** Since the fungus survives on crop refuses, burning the refuse or deep plowing to bury any plant ruminant in the field reduces primary inoculum. Use resistant/tolerant maize varieties.

### **Brown spot**

**Causal agent:** *Physoderma maydis*

**Symptoms:** Lesions first appear as very small, round, and yellow spots appear on maize foliage. Lesions may occur in bands across leaf blade and then enlarged by coalescing. Cells of infected tissues disintegrate and expose pustules containing golden brown to dark brown sporangia that provide characteristic color (Fig.9). Nodes infected plants usually break easily.



**Figure 9. Brown spot of maize caused by *Physoderma maydis***

**Disease cycle:** Sporangia overwinter or survive in infected tissue or in soil and germinate in the presence of moisture to produce zoospores. These move in water to infect young maize tissue. Disease development is favored by relatively high temperature (23 - 30°C) and heavy rain during the crop season.

**Control measures:** Use resistant variety and avoid farm operation during dew period. Deep plowing usually burry crop debris in the soil that avoid contact of the pathogen and the young maize plant.

### **Downy mildew**

**Causal agent:** Downy mildew in maize is cause by some species of *Sclerospora* (Figure 10).



**Symptoms:** Infected leaves show long chlorotic streaks with downy growth of sporangia and sporangiophores (Figure 10). If infection occurs early, plants are stunted and may die.



**Figure 10. Downy mildew of maize caused by *Sclerospora* spp.**

**Disease cycle:** The pathogen survives on other hosts such as sugarcane, sorghum, Sudan grass etc. plant parts. Spores usually develop when weather conditions become conducive on these crop residues. These spores initiate disease in new crop and may move a long distance by wind. Secondary spread of the disease within and between fields occurs by conidia produced from lesions. Disease

development is favored by moderate temperature (18 - 27°C) and heavy dews during crop season. Most downy mildews in maize are seed transmitted diseases.

**Control measures:** Grow maize in disease-free areas, rogue and destroy diseased plants, isolate maize from host plants, and choose resistant variety. Use crop rotation. Seed treatment with systemic fungicides can eradicate deep sited pathogens.

### **Ear and stalk diseases**

#### **Common smut diseases**

**Causal agent:** Common smut is caused a fungus called *Ustilago maydis* (Figure 11)

**Description:** Leaves, stalks, ear, or tassels may be replaced by black spore mass which is covered by a persistent grayish membrane. "Boils" or irregular growths are common. High nitrogen fertilization increases the disease while phosphorus tends to decrease.



**Figure 11. Common smut of maize caused by *Ustilago maydis***

**Disease cycle:** The teliospores overwinter in crop debris and soil, where they stay viable for several years. They germinate to produce sporidia that are disseminated to young maize plant. Only bi nucleate hyphae can infect maize plant. Host cells surrounding the fungal hyphae are stimulated to enlarge and form galls. This increases in number and size to cause a typical sign like that shown in Figure 15.

**Control measures:** Trace of smut usually found in every field. Hybrids vary in susceptibility. Hail damage or various stresses increase risk of smut. Crop rotation, sanitation, and seed treatment with systemic fungicides are some of the options to integrate for effective control.



## Head smut

**Causal agent:** Head smut in maize is caused by *Sphacelotheca reiliana* (Figure 12).

**Symptoms:** Spores infect plant systemically while in seedling stage, causing possible stunting, but only tassels and ears are smutted. Black spore masses covered with only a thin membrane which easily breaks up (in contrast to common smut). Thread-like strands occur in the spore masses.



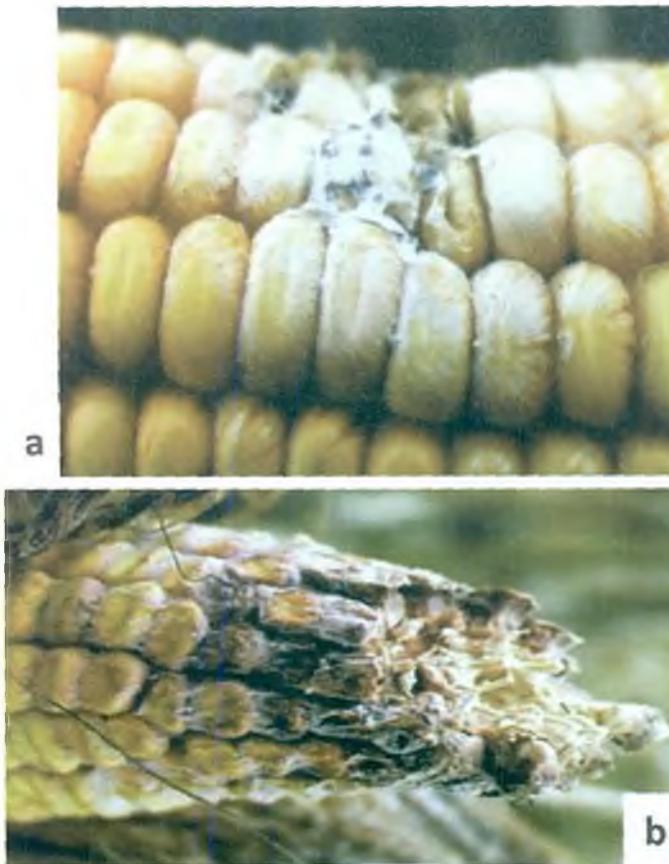
**Fig.12. Signs of head smut in maize reproductive parts, (a) and (b).**

**Disease control:** Crop rotation reduces risk of infection due to soil borne inocula of the pathogen. Most hybrids are resistant. Seed treatment with systemic fungicide eradicates seed borne inoculums and protects young maize seedling from soil borne infection.

### 3.2.3. Ear and kernel rot diseases

**Causal agents:** Ear and kernel rot diseases are caused by various fungi that include *Diplodia* spp., *Fusarium* spp., *Aspegillus flavous*, etc (Fig. 13)

**Description:** Kernels of ears turn pink to red to black with associated mold growth. Often, this is associated with insect injuries or with other injuries and very wet conditions.



**Fig. 13. Ear rot infection could start either from the middle (a) or from the tip (b).**

**Epidemiology:** Most important sources of these diseases are diseased stalks, crop debris, airborne spores, and processing spaces.

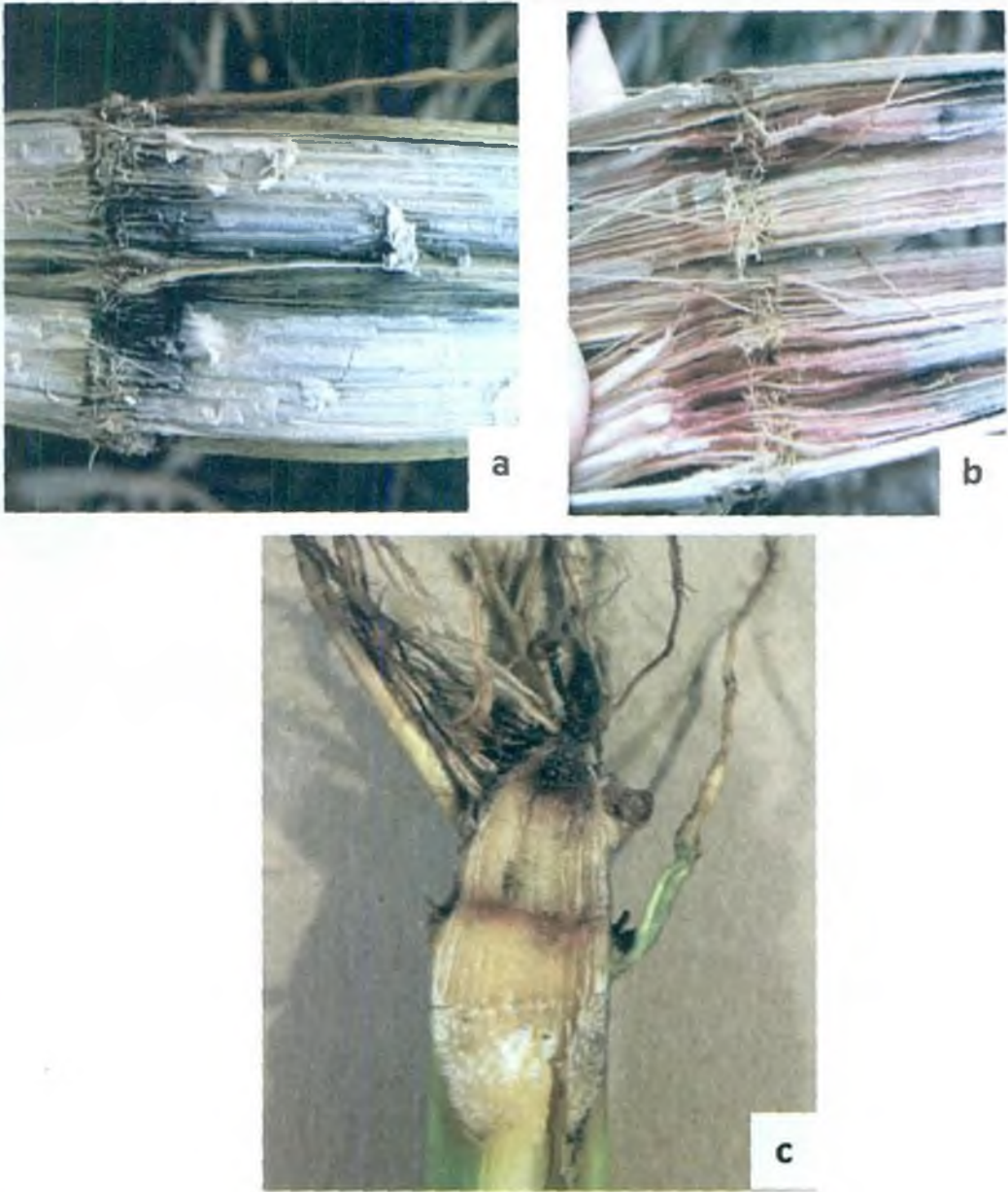
Hybrids vary in resistance to ear molds. Reducing insect damage may also reduce ear mold damage. Proper storage and treat seed before storage. Crop rotation may reduce the risk of seed exposure to fungi in soil and reduce stalk infection.

#### **3.2.4. Stalk rot diseases**

**Causal agents:** Stalk rots of maize are caused by various fungi that include *Diplodia* spp., *Fusarium* spp., etc (Fig.14)

**Description:** Stalks are weak; the pith is shredded and discolored, often pink to red. Lodging frequently occurs. Yield losses occur due to poor filling of ears, early ear drop, and stalk breakage.





**Fig.14. Maize stalk rots caused by different fungi**

**Epidemiology:** These fungi overwinter in stalk debris that either buried or on the soil surface. Under warm and moist conditions, the spores disseminate and infect new crop. Infections may occur through

crown or root and then develop to the upper parts. The diseases are common in Ethiopia.

**Management:** Crop rotation to non-cereal crops is beneficial. Proper management of soil fertility reduces stalk rots. Hybrids vary in resistance to stalk rot as well. If stalk rot present, harvesting early reduces ear loss.

### 3.2.5. Kernel diseases

There are many kernel diseases of maize in Ethiopia that occur in storage and considered to have an intermediate importance. These diseases are caused by many fungal species that include *Fusarium* spp., *Phoma* spp., *Acremonium* sp., *Negrospora* sp., *Aspergillus flavous*, and *Penicillium* spp. and some bacteria including *Pseudomonas* sp. Pictures are included to facilitate identification during seed testing and general management strategies are briefly given at the end (Fig. 15, Fig 16, and Fig 17).



**Fig.15. *Fusarium moniliformae* infection on seeds**

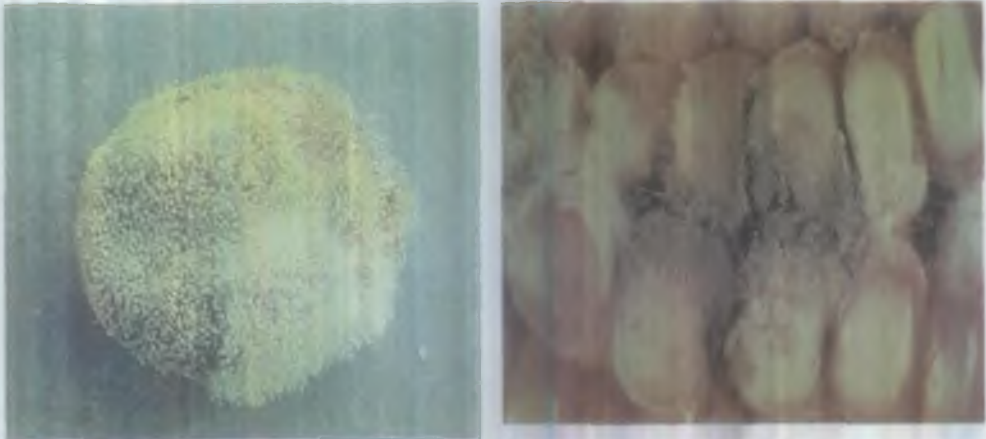


**Fig.16. *Acremonium* infection on adult plants**





**Fig.17. *Negrospora* infection on seed**



**Fig.18. *Aspergillus flavous* (left) and *A. flavous* growth on maize seeds (right)**



**Fig.19. *Penicillium* fructification (left) and *Penicillium* spp. infected maize kernels (right)**

**Management strategies:** Resistance is one aspect of management because most improved varieties show differences in seed infection. Proper storage of kernels after harvest prevents the invasion and then accumulation of mycotoxins on the product. Seed treatment of kernel before storage, store hygiene, maintaining balanced moisture and temperature in the store, control of insect damage on kernels together reduce the severity of kernel diseases in storage.

### **3.3. Bacterial diseases**

#### **3.3.1. Bacterial stalk rots**

**Causal agent:** Stalk rot in Ethiopia is mainly caused by *Erwinia caratovora* ( Fig. 20)

**Symptoms:** Generally the disease appears in the midseason when plant canopy closes. The internode above the soil line turns tan to dark brown, water-soaked, soft or slimy and collapsed. Collapsed and twisted stalks are a good indication of bacterial stalk rots.



**Fig. 20. Bacterial stalk rot caused by *Erwinia* sp. (a) some plants showing wilting symptoms, and (b) roots and collar parts of the maize plant damaged by the bacterium.**

**Disease cycle:** Bacteria live saprophytically on crop residue in the soil and invade maize plants through stomata, hydathodes or wounds on leaves and stalks. It may be seedborne. The disease is favored by high rainfall and temperature with poor air circulation and drainage.

**Control measures:** Use resistant varieties (when available) and apply good agricultural practices that avoid flooding.



### 3.3.2. Bacterial leaf streak

**Causal agent:** this disease is caused by a bacterium called *Psuedomonas syringae* pv. *Cononafaciens* (Figure 21).

**Symptoms:** Small, irregular shaped spots, with a water-soaked appearance at first, followed by spots turning a creamy white to tan, resembling parchment paper. It is sometimes called chocolate spot due to its color. This disease is favored by warm and wet weather with severe winds.



**Figure 21. Bacterial leaf streak of maize on leaves**

**Disease cycle:** The bacteria overwinter in crop residue and invade maize through stomata. Many grasses can be sources of primary inoculums. It occurs only in potassium deficient soils.

**Control measures:** Apply potassium containing fertilizer. Crop rotation reduces overwintering of bacteria. Good weed control early in the season reduces the chance of primary infection. It is seldom serious only when the weather turns too hot to be favorable for continued bacterial infection. Resistant varieties are often recommended.

### **3.4. Virus diseases**

#### **3.4.1. Maize streak disease**

**Causal agent:** Maize streak virus (MSV)

**Description:** MSV causes almost continuous, narrow, chlorotic streaks centered on secondary and tertiary leaf veins. The lesions are distributed uniformly over the leaf surface. Complete fusion may occur between the parallel chlorotic streaks. Ears produced on infected plants contain few or no seeds. This disease is transmitted by several species of leafhoppers. This disease is not seed transmitted (Fig. 22).



**Fig. 22. Streak caused by *Maize Streak Virus***

**Management:** Resistance is most effective way to control this disease, but controlling the vector by insecticide may also help. Since the vectors persistently transmit the virus, this is very useful practice. Plant maize away of infected hosts such as wheat, barley, oats and rye.

### **3.4.2. Maize dwarf mosaic virus**

**Causal agent:** this is caused by a virus known as *Maize dwarf mosaic virus*



**Description:** Light green mottle or mosaic forms on upper leaves, but not reddening symptoms. Upper portion of plant may be stunted. This virus is transmitted by aphids. It is seed transmitted to some extent, mechanically by leaf rubbing, airbrushing, etc. ( Fig. 23).



**Fig. 23. Maize dwarf disease caused by *Maize Dwarf Mosaic Virus***

**Management:** Hybrids may vary in resistance, hence select good maize variety. The disease is rare in colder climates in Ethiopia. It is transmitted by aphids that may move into the crop areas from other places. Vector control should combine with other control measures. Control weed (especially Johnson grass) hosts to reduce initial inoculum. Avoid late planting that enhances high vector population.

## **Bibliography**

- EIAR. 2001. የአዝርዕት ጥበቃ መመሪያ (Guide to Crop Protection Technologies). EIAR, Addis Ababa.
- Girma T., Fekede A., Temam H., Tewabech T., Eshetu B., Melkamu A., Girma D., and Kiros M. 2008. Review of maize, sorghum and millet pathology research. Pages 245-302. In: Abraham Tadesse (ed.). Increasing crop production through improved plant protection. Vol. I. PPSE and EIAR, 2008. Addis Ababa.
- Donald G. White. 1999. Compendium of corn diseases, Third Edition. ISBN 978-0-89054-234-7 (APSnet, online).
- CIMMYT. 2001. Seed testing of wheat and maize: A laboratory guide. CABI for CIMMYT, Walingford.

## Section 4

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### **Pests of Stored Maize and Their Management Options**

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#### **4.1. Introduction**

Maize produced for seed or grain should be stored for at least some time after production (until the next season planting). The storage period could range from some months to several years. During these periods numerous pests could cause significant damage and loss to the produce. The most important group of storage pests are insects followed by rodents, although sometimes in some localities it may be vice versa. The different groups of pests of stored seeds in general and that of maize in particular are described and their management options are given in this section.

#### **4.2. Insect pests of stored maize**

The majority of storage insects belong to the insect order of Coleoptera which contains beetles followed by Lepidoptera (moths and butter flies). The adults of many important beetle pests also feed on the stored food, but the adults of some beetle pests and all moth pests are short lived and do not feed. The immature insects (larvae)



that develop from the eggs have evolved as rather simple stages designed for feeding and growing, hence, cause much of the damage to the stored seed. Of the numerous insect pests in storage only a few are of economic importance in Ethiopia.

Storage insect pests could generally be grouped as primary or secondary pests. Primary pests are those which damage previously undamaged seed while secondary pests are those which cannot damage sound seed but attack seeds which are already damaged either mechanically or by primary pests. However, the term primary or secondary is not related to the degree of damage they cause.

#### **4.2.1. Primary insect pests**

**Weevils: Maize weevil (*Sitophilus zeamais* Motsch.) and Rice weevil (*S. oryzae* (L.))**

Weevils are the most common and destructive insect pests of maize and other cereals in storage. There are three species of weevils: The maize weevil (*S. zeamais*), rice weevil (*S. oryzae*) and granary weevil (*S. granarius*). The body colour can range from light to dark brown, and have long beak or rostrum and elbowed antennae that distinguish them from all other common storage pests. The granary weevil is not a common pest in Ethiopia. The maize weevil and rice weevil are very similar in their morphology and biology. It is not

possible to separate them from each other by external morphological characteristics. Both species usually have four pale redish-brown or orange-brown oval markings on the elytra (Fig. 1), although it is sometimes indistinct. Both species are very common in maize and other cereals stores in all areas in Ethiopia.



**Fig. 1. Maize weevil**

**Source: [keys.lucidcentral.org](https://keys.lucidcentral.org)**

Often weevil infestation starts in the field long before harvest where it completes one or two lifecycles. The adults are long-lived (several months to one year), and eggs are laid throughout the adult life. The larvae are whitish, legless grubs (Fig. 2) and develop and pupate inside a single grain. Adult weevils emerge through round holes in the kernels bored by the larvae before pupation. The damage is distinct (Fig. 3). These holes are the evidence that a produce is infested with weevils. Both adults and larvae of weevils feed on the endosperm of maize seed.

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**Fig. 2. Larvae of *Sitophilus* species**  
**Source: Flickr.com**



**Fig. 3. Maize grain severely damage by weevils**  
**Source: Flickr.com**

### **Management of weevils**

Since weevils and other primary insect pests such as LGB and Angoumois grain moth infestations start in the field, field sanitation and crop rotation can help reduce the problem. Use of maize varieties with tight and complete husk cover will protect cobs from field infestation. Prompt harvesting, proper drying and cooling grain before storage, storing in cool and dry place in clean storage facilities without mixing with old seed stock are some of the important management options to be followed. Seed treatment with insecticide chemicals should follow after all of these practices if effective control is to be achieved. Weevils can effectively be controlled by synthetic insecticides, dilute dusts or sprays. Insecticides can be applied to empty warehouse before intake of new stocks, surface treatment on bags stacks and space treatment especially done by fogging in a tightly sealable store for flying pests.

The organophosphates pirimiphos-methyl 2% D (at 25-50 g/q), Malathion 5% D (50 g/q) and fenitrothion are the commonly recommended insecticides. They are effective against most stored grain insect pests, except LGB. A residual insecticide should be sprayed to the floor and structure walls. After the bin is filled, a residual spray should be applied to the grain surface as well. Fumigation is another option which should be considered as a last resort. Aluminum phosphide tablets are commonly used fumigants in Ethiopia. Successful fumigation depends on quality of sealing,





**Fig. 2.** Larvae of *Sitophilus* species  
Source: Flickr.com



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quality of the fumigation sheet (many plastic materials do not fulfill the requirements of sufficiently gas-tight, low weight and resistant to mechanical damage), correct dosage and application of fumigants and sufficient exposure time.

**Larger grain borer (*Prostephanus truncatus* (Horn)) and Lesser grain borer (*Rhyzopertha dominica* (F.))**

The two species of grain borers are morphologically very similar, although the larger grain borer (LGB) is larger (3-4.5 mm long) than the lesser grain borer (2-3 mm long). They are cylindrical beetles with the head deflexed under the thorax so that it is invisible from above. In the lesser grain borer the elytra are gently convex at the tip (Figure 4) rather than flattened. In the larger grain borer the declivity is flattened and steep (Figure 5).



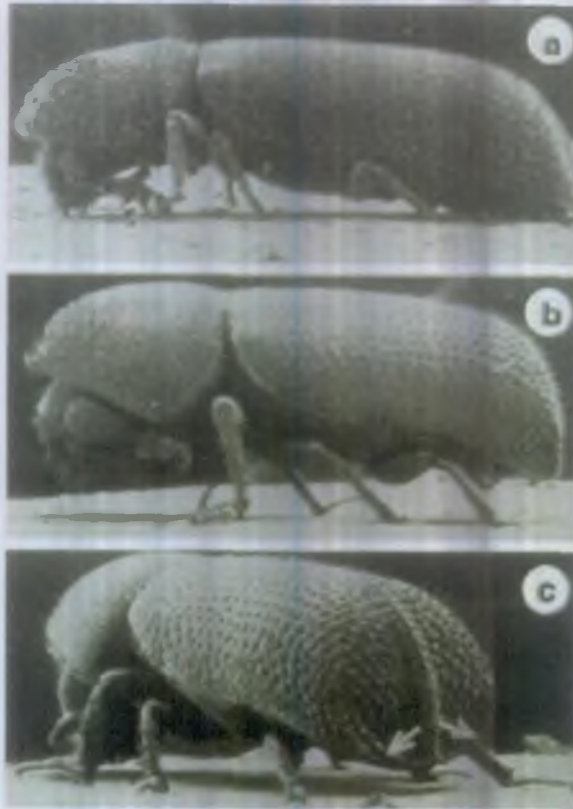


**Fig.4. Lesser grain borer**  
Source: [knowledgebank.irri.org](http://knowledgebank.irri.org)



**Fig. 5. Larger grain borer (LGB)**  
Source: [gipsa.usda.gov](http://gipsa.usda.gov)

The difference between the lesser and larger grain borer species is depicted in Fig. 6 below.



**Fig. 6. a lesser, b and c LGB (characteristic truncated posterior)**  
Source: [ipmworld.umn.edu](http://ipmworld.umn.edu)

Beetles in this family are adapted to boring into hard substances such as wood and are capable of attacking previously undamaged grain where they can cause serious damage. They may also sometimes be found attacking the timber of storage structures. Both the adults and larvae are capable of boring into and feeding on a wide range of commodities. They can develop on grain with moisture content as low as 9%. Like weevils, they start attacking maize in the field before harvest. Eggs are laid throughout the infested grain. The hatching larvae are immobile and live within the grain or in the flour that accumulates with infestation. The larvae of the lesser grain borer are white and parallel sided (i.e. they do not taper). Larvae of the larger grain borer have thoracic segments considerably larger than those of the abdomen (Fig. 7).



**Fig. 7. Larva of LGB**  
**Source: [agpsrv34.agric.wa.gov.au](http://agpsrv34.agric.wa.gov.au)**

LGB adult bore into the maize grains, making neat round/ irregular holes, and as they tunnel from grain to grain they generate large quantities of maize dust (Fig. 8 and 9).



**Fig. 8. Light infestation by LGB**

Source: internet



**Fig. 9. Maize heavily damaged and undamaged by LGB**

Source: [apps.cimmyt.org](http://apps.cimmyt.org)



### **Management of LGB**

This is also a primary pest that can be managed using the methods recommended for weevils. Regarding insecticide chemicals, the commonly used organophosphates for the control of most stored grain pests are less effective against the larger grain borer. Thus, synthetic pyrethroids deltamethrin and permethrin are recommended to be used in mixture with the organophosphates. There are mixed formulation such as Actellic supper. A residual insecticide should be sprayed to the floor and structure walls. After the bin is filled, a residual spray should be applied to the grain surface as well. For biological control, the introduction of a natural enemy to control an introduced pest is being used against LGB in several African countries. The larger grain borer which was accidentally introduced in Africa in 1970s has now reached to 20 countries including Ethiopia. A predator beetle (*Teretrius (Teretriosoma) nigrescens*) has been introduced and released for LGB management in some affected African countries such as Benin, Ghana, Guinea, Kenya, Malawi, Tanzania, Tog, and Zambia. In addition, many indigenous natural enemies of other insect pests of stored grains have been recorded from farm-stored maize in Ethiopia indicating the possibility of using predators and parasitoids in the management of insect pests of stored grain.

**Angoumois grain moth (*Sitotroga cerealella* (Olivier.))**

A small (smaller than other storage moths pests) cream- or yellowish brown colored moth sometimes with a small black spot on the forewing, the wings are very narrow and fringed with long hairs; the sharply pointed tip of the hindwing is characteristic (Fig. 10). The fringe hairs on the hind-wings are longer than half the width of the wing.



**Fig. 10. Angoumois grain moth**  
**Source: internet**

It may start infestation in the field. In the store damage may be very serious on maize stored unshelled. Damage is more limited with shelled grain as the moths do not penetrate more than a few centimeters from the surface. The developing larvae cause all damage, as the adults do not. The larvae develop within the grain and upon emergence a characteristic hole is left behind (Figure 11).



**Fig. 11. Cob maize infested and damaged by the Angoumois grain moth**

**Source: [keys.lucidcentral.org](http://keys.lucidcentral.org)**

The larger grain size and hence intergranular spaces of maize allow some movement of *S. cerealella* in shelled grain and thus increase the chance of re-infestation in grain bulks. This is not common with the smaller more tightly-packed grains but when it occurs infestations are usually confined to the surface and the periphery of bulks. The larvae bore into the grain where they will complete their development. The newly emerged adult pushes through the window of the seed coat, leaving a small, but characteristic, round hole, usually in the crown end of the grain. Adults are strong fliers and can disperse easily. However, they are not strong enough to penetrate deep and can only infest the outermost layers of stored grain if it is closely packed.



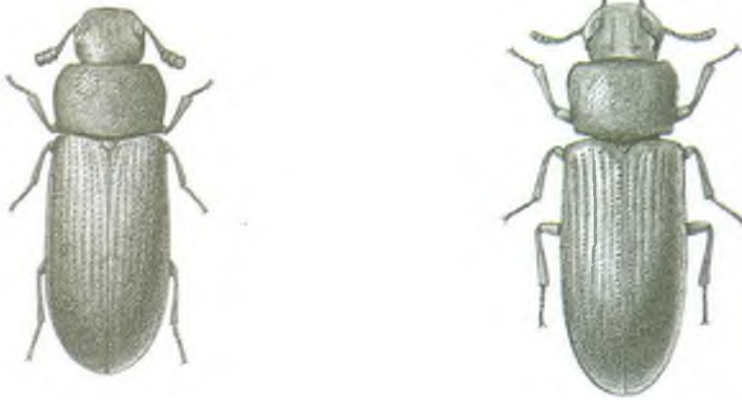
### **Management of Angoumois grain moth**

This is also one of the important primary pests of maize. The same management options recommended for weevils are effective against this insect.

### **4.2.2. Secondary insect pests**

#### **Rust-red flour beetle (*Tribolium castaneum* (Herbst)) and Confused flour beetle (*Tribolium confusum* (J. De Val))**

These are reddish-brown in color and parallel-sided beetles very similar in appearance but may be distinguished from each other by certain features of the eyes and antennae. In the red flour beetle the antennae end in a three-segmented club (Figure 12 left). Whereas in the confused flour beetle the antennae end is gradually club-like, the "club" consisting of four segments (Figure 12 right). Both beetles live in the same environment and compete for resources. The red flour beetle may fly, but the confused flour beetle does not fly. Eggs, larvae, and pupae from both species are very similar and are found in similar environments.



**Fig. 12. Red flour beetle (left), and Confused flour beetle (right)**  
**Source: internet**

The slender larvae are creamy yellow to light brown in color. They have two dark pointed projections on the last body segment (Figure 13). These beetles can breed throughout the year in warm areas and the adult can live for three years.



**Fig. 13. *T. castaneum* (adult and larva)**  
**Source: ars.usda.gov**

They are very important and common secondary pests of cereals, having a preference for the embryo, but they cannot multiply rapidly on dry cereal grains, if these are undamaged and free of grain fragments or other dockage. They can penetrate deeply into the stored commodity. Infestation by these beetles leads to persistent disagreeable odours in the commodity. They have been recorded in large numbers in maize samples collected from all maize growing Ethiopia.

#### **Management of flour beetles**

Management options applied for the primary pests indicated above can control these insects effectively.

#### **Indian meal moth (*Plodia interpunctella*)**

The Indian meal moth is easy to distinguish from other grain moth pests by the peculiar markings of the forewings (Fig. 14); they are reddish brown with a copper luster on the outer two-thirds, but whitish gray on the inner or body ends. The hind wings lack distinctive markings and are more or less uniformly gray. Adults can be seen resting on the grain surface or grain bin walls.





**Fig. 14. Indian meal moths at rest (left) and wings spread (right)**

**Source: [dpi.qld.gov.au](http://dpi.qld.gov.au)**

They fly at night and are attracted to lights. Eggs are deposited on the grain surface singularly or in groups of 12 to 30. Because of their small size, they are difficult to see without the aid of a microscope. Newly hatched larvae are very small and difficult to see. Larger larvae are usually yellowish, greenish, or pinkish. Larvae of the meal moth spin a web as they become fully grown and leave behind silken threads wherever they crawl. The webbing is often sufficiently abundant to attract attention (Figure 15). Webbing produced by larvae can block machinery during processing.



**Fig.15. Indian meal moth larva on damaged cob maize**  
**Source: internet**

The larval stage lasts from two weeks to one year, and is responsible for grain losses. In grain, larval feeding is usually restricted to the top one to two inches. Large larvae feed on the grain germ. When fully grown, larvae spin a silken cocoon and transform into light-brown pupae. The cocoons and pupae can be seen on the grain surface and walls of grain bins. The larvae are surface feeders. Most of the "damage" to stored products occurs when the larvae spin massive amounts of silk that accumulate fecal pellets, cast skins, and egg shells in food products. The damage to stored products due to this contamination exceeds the amount of food eaten by the insects.

### Management of Indian meal moth

Cultural and chemical management options recommended for the control of primary insect pests can effectively control Indian meal moth.

### Tropical warehouse moth (*Ephestia cautella* (Walker) and other *Ephestia* spp.

The tropical warehouse moth (also called almond or cacao moth) has brown-grey forewings with a darker band running across the middle and far edges. The wings also have a fringe of hair. The wingspan is approximately 15 - 20 mm and when at rest its length is between 10 - 12 mm. (Figure 16 A).



**Fig. 16 A. *E. cautella* at rest (left) and wings spread (right)**

**Source: [agspsrv34.agric.wa.gov.au](http://agspsrv34.agric.wa.gov.au)**

All *Ephestia* species have broader wings than the Angoumois grain moth and a shorter fringe of hairs. *Ephestia* spp. have dark forewings, sometimes indistinctly banded, and paler hindwings. The eggs hatch



in around 4 - 8 days and begin to spin immediately. The yellow-white larvae grow up to 14 mm long; have a brown head and a dark spot at the base of the back hairs (Figure 16B). The larva pupates in a cocoon either within or around the infested material. Larvae which are free-living caterpillars spin silk as they move (which is both a problem in itself and often the first visible sign of infestation).



**Fig. 16 B. *Ephestia cautella* adult and larva**

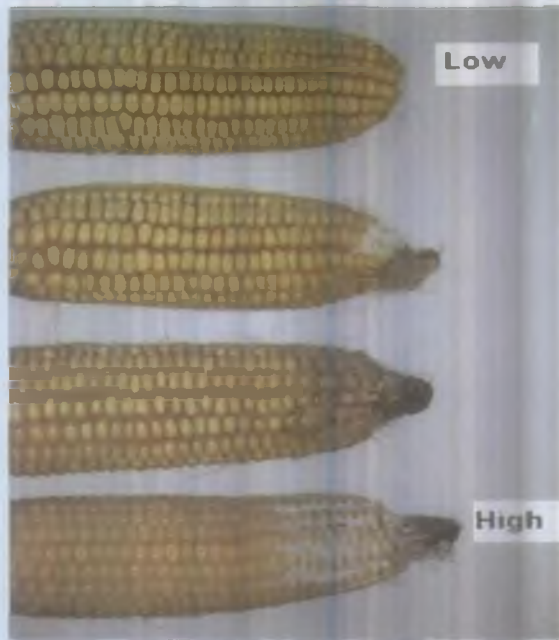
**Source: internet**

### **Management of warehouse moths**

Cultural and chemical management options recommended for the control of primary insect pests can effectively control the warehouse moths.

### 4.3. Storage diseases (grain moulds)

Fungi are the most common causes of diseases associated with maize seeds in storage. The filamentous fungi or mold that occur in cereal grains are traditionally divided into two groups, depending on when they predominate in grain in relation to available moisture in the grain. These groups have been referred to as field fungi and storage fungi. Some fungi can grow both before and after harvest. Storage fungi often contaminate crops (ear rot) in the field at very low levels. They only start to grow and reach significant levels in store, when the moisture level drops. Field fungi include species of *Alternaria*, *Cladosporium*, *Fusarium*, *Helminthosporium*, *Phoma* and *Rhizopus* spp. The main storage fungi are species of *Aspergillus* and *Penicillium* ([www.foodquality.com](http://www.foodquality.com)). Three toxic species of *Fusarium* (*F. moniliformae*, *F. subglutinans*, and *F. graminearum*) were found to be highly associated with maize samples (Fig. 17 a, and b).



**Fig. 17 a. grain mold on cob maize**  
Sources: [nkcropbarometer.wordpress.com](http://nkcropbarometer.wordpress.com)



**Fig. 17 b. Aspergillus flavus on shelled maize**

Source: [agnet.org](http://agnet.org)



The major effects of fungal deterioration of seeds include decreased germination, discoloration, development of visible mold growth, musty or sour odors, dry matter loss and nutritional heating, caking, and the potential for production of mycotoxins in the grain. Decreased germination of the seed occurs when storage fungi invade the germs or embryos of the grain kernel. Musty odors may become apparent before mold growth becomes visible and is an early warning of mold activity, as is heating.

#### **Management of storage diseases**

Sanitation measures, selection of uninfected cobs for storage, drying to a proper moisture content, etc. can reduce mould infection in storage. Grain moisture can increase in storage due to insect infestation; hence, controlling insect pests can control moulds. To prevent spoilage by storage fungi, the moisture content of starchy cereals grains should not exceed 13%.

#### **Rodent pests of stored maize**

Rodents can cause a variety of problems in a seed store, and these are generally applicable to all food store situations, from small-scale on-farm storage to large-scale silos or warehouses. On average rodents consume about 10% of their body weight per day. There have been various attempts to measure food lost to rodents under real conditions but this has been difficult to accomplish. Measuring the actual consumption of a rodent population in food store is difficult.

condition of grain in storage should be monitored frequently for timely action.

## **Bibliography**

- Abraham Tadesse. 1991. The biology, significance and control of the maize weevil, *Sitophilus zeamais* Motsch. (Coleoptera: Curculionidae) on stored maize. MSc. Thesis, AUA, Alemaya, Ethiopia.
- Abraham Tadesse. 1997. Arthropods associated with stored maize and farmers' management practices in the Bako area. *Pest Management Journal of Ethiopia*. 1(land 2): 19-27.
- Abraham Tadesse. 2003. Studies on some non-chemical insect pest management options on farm-stored maize in Ethiopia. Dr. agr. thesis, Justus-Libieg-University Giessen, Germany. ISBN 3-935713-68-1. 246 pp.
- Abraham Tadesse, Amare Ayalew, Emana Getu and Tadele Tefera. 2008. Review of research on post-harvest pests. PP. 475-562. In: Abraham Tadesse (ed.). Increasing crop production through improved plant protection. Volume I. Plant Protection Society of Ethiopia (PPSE), PPSE and EIAR. Addis Ababa, Ethiopia.
- Gewinner, J. 1996. Manual of the prevention of post-harvest grain losses. GTZ GmbH, Eschborn, FRG. 330 pp.
- Golob, P.; Farrell, G. and Orchard, J. E. (eds.). 2002. Crop post-harvest: Science and technology, Volume I Principles and practices. Blackwell Science Ltd. 554 pp.

- Haines, C. P. (ed.). 1991. Insects and arachnids of tropical stored products: Their biology and identification (a training manual), (2<sup>nd</sup> edition). Natural Resources Institute (NRI), Chatham, UK. 246 pp.
- Hill, Dennis S. 2002. Pests of stored foodstuffs and their control. Kluwer Academic Publishers, London, UK.
- Lloyd B. Bullerman and Andreia Bianchini. 2011. *The microbiology of cereals and cereal products: Variety of media and methods available for detection and enumeration of molds in cereal products. From: Food Quality magazine, February/March 2011. ([www.foodquality.com](http://www.foodquality.com))*.
- Tesfaye Wubet. 1997. *Fusarium* and *Fusarium* toxins in maize in some regions of Ethiopia. M. Sc. Thesis, Addis Ababa University, Addis Ababa, Ethiopia.
- Tesfaye Wubet and Dawit Abate. 1999. Toxigenic *Fusarium* species in maize grain in Ethiopia. Pp. 132-134. *In: CIMMYT (International Maize and Wheat Improvement Center) and EARO (Ethiopian Agricultural Research Organization). Maize production technology for the future: Challenges and opportunities: Proceedings of the 6<sup>th</sup> eastern and southern Africa Regional Maize Conference, 21-25 September, 1998, Addis Ababa, Ethiopia: CIMMYT and EARO.*
- Tesfaye W. and Dawit A. 2000. Common toxigenic *Fusarium* species in maize grain in Ethiopia. *SINET Ethiopian J. Sci.* 23: 73-86.



