ASSESSMENT OF MAIZE EAR ROT IN MAJOR MAIZE GROWING AREAS OF ASHANTI REGION OF GHANA

BY

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JUNE, 2014

KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY,

KUMASI, GHANA

SCHOOL OF GRADUATE STUDIES

DEPARTMENT OF CROP AND SOIL SCIENCES

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In Partial Fulfillment of the Requirement for the Degree

Of

Master of Science in Crop Protection (Plant Pathology)

JUNE, 2014

DECLARATION

I, Herbert Klay Kieh, do hereby declare that this submission is my own work towards the Master of Science degree in Crop Protection (Plant Pathology) and that, to the best of my knowledge, it contains no material previously published by another person or material which has been accepted for the award of any other degree of the university, except where due acknowledgement has been made in the text.

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ABSTRACT

Maize ear rots reduce grain yield quality with implication on food security and health. Information on the types and prevalence of maize ear rots in the major maize growing areas of Ashanti Region of Ghana is scanty. A survey was, therefore, conducted during the major and minor maize growing seasons to determine the prevalence of maize ear rots and types of fungal pathogens associated in this region. The survey considered 39 and 20 communities in metropolis, municipals and districts during the major and minor seasons, respectively. A total of 44 farmers were interviewed during the survey. The field survey showed a 70% female dominance amongst respondents and a predominantly middle-age farming population. Majority (77%) of the farmers interviewed had only primary school education and about 43% had over two decades of experience with maize cultivation. Most of the farmers obtained their seeds from the Ghana Seed Company, and Obaatanpa appeared to be the variety of choice amongst farmers in the region. About 66% of the respondents alluded to planting their seeds in the month of April and majority (84%) of the farmers observed symptoms of maize ear rot at maturity of the crop. The survey also considered management practices used by farmers to combat maize ear rot. The results showed that majority (68%) of the farmers had no prior knowledge of any fungicides. Roundup, a weedicide, appeared to be the chemical of choice but none of the farmers interviewed used a fungicide. Sun drying of debris appeared to be the popular control method used in the region. The maize samples collected from the communities were taken to the laboratory and analyzed for ear rot pathogens. During the major season, a total of seven fungal pathogens were isolated. For this period, the prevalent fungal pathogen of maize ear rot was *Aspergillus flavus,* followed by *Colletotrichum* sp. and the least being *Curvularia* sp. For the minor season, a total of five fungal pathogens were isolated. During this period, the prevalent fungal pathogen of maize ear rot was *Colletotrichum* sp., followed by *A. flavus* and the least being *Penicillium* sp. The types of maize ear rot identified were *Aspergillus flavus*, *Colletotrichum* sp., *Trichoderma* sp., *Fusarium* sp., *Aspergillus niger*, *Penicillium* sp. and *Curvularia sp*. Results from the field survey showed that majority of the farmers did not perceive the occurrence and impact of maize ear rots.

DEDICATION

I dedicate this work to loving memory of my parents Mr. and Mrs. Albert T. Kieh, my wife Mrs. Anna Koon Kieh, and my children: Charles Koon, Austin Koon, Priscillia B.Y. Kieh, Priscilla T. Kieh, Janet M. Kieh, Theodosia D. Kieh and Herbert Klay Kieh, Jr.

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CHAPTER ONE

1.0 INTRODUCTION

1.1 Background

Maize (*Zea mays* L.) is an essential agricultural crop grown widely throughout the world in a range of agro-ecological environments. It is the most important cereal crop produced in Ghana and also the most widely consumed staple food, with increasing production since 1965 (Morris *et al*., 1999; FAO, 2008). The production of maize is done under rain-fed condition by small holder resource-poor farmers (SARI, 1996).

Maize is an excellent source of dietary protein, carbohydrate, saturated fats, polyunsaturated fats, monounsaturated fats, minerals and vitamins (FAO, 2008). It is rich in dietary fibre and calories which are good sources of energy. Despite the excellent benefits offered by maize consumption, the survival of the cereal is under constant threat as maize is quite susceptible to a variety of ear and kernel rots (IITA, 2009).

In developed countries, maize is mostly used as feed for livestock and as raw materials for industrial production; while in developing countries, the crop is mostly used for human consumption (IITA, 2007). According to Romains (2001), about 66 % of maize produced worldwide is used for feeding livestock, 25 % for human feeding livestock and 9 % for industrial and seed purposes. Due to its starchy composition, maize is transformed into several consumable forms such as beer, roasted cobs, porridges, pastes, grits and green fresh maize. According to the Ministry of Food and Agriculture of Ghana (MoFA, 2000), the per capital consumption of maize in 2000 was 42.5 kg.

In Ghana, several improved maize varieties with different maturity periods have been developed by the CSIR-Crops Research Institute to meet the growing needs of maize consumers in the country (Twumasi-Afriyie *et al*., 1997). These varieties include Obaatampa, Dadaba, Abeleehi, Okomasa, Mamaba, CIDA-ba and Golden Jubilee. The Obatanpa, Dadaba, Mamaba, CIDA-ba and Golden Jubilee are quality protein maize (QPM) with adequate protein than most modern varieties of tropical maize. Their relatively high nutritive value and high yielding potential make them the varieties of choice for most farmers (Asiedu *et al*., 2001).

Maize production in Sub-Saharan Africa is hindered by many diseases and pests that attack the crop. These include ear rots, leaf blight, downy mildew, rust, maize streak, mould grain, leaf spots, stem and ear borers, army and cut worm's infestations, white grubs and grain borers amongst others (Davis and Pidigo, 1990).

The problem of fungal infections, in general, and maize ear rots, in particular, has been reported to cause serious damage to the crop. Ear rots infection leads to reduced maize yield and ear contamination. The stressful and risk factors that are very effective in the development of maize ear rot and mould grain are moisture stress, ear injury, extreme weather conditions, infected crop residue, the growing of continuous crop, damage grain, high moisture, storage conditions and the use of susceptible hybrids (Corn Disease Profile 111, 2012).

Maize ear and kernel rots reduce crop yield and diminish nutritional quality, thereby resulting in a threat to global food security (Kommendal and Windals, 1981). The control of ear rot has, thus, become a major concern in many developing countries where maize is grown and consumed. High temperature and rain can cause maize ear rot, resulting to the production of mycotoxin under post- harvest condition (CAST, 2003). Health hazard posed by ear rot cannot be over emphasized, as heavy infection of ear rot on maize can result in spoilage of the grains, reducing yield and quality and the subsequent production of secondary metabolites mycotoxins causing mycotoxicoses and carcinomas of humans and domestic animals (Marasas *et al.*, 1988; Rabie *et al*., 1993; Julian *et al*., 1995; Castelo *et al*., 1998). Aspergillus ear rot can produce aflatoxin which causes poisoning of livestock and cancer as well as birth defects in humans (Robertson-Hoyt *et. al.,* 2006). The effects of mycotoxins production can also lead to feed refusal, damage to the liver, reduced conception, reduction in grain or kernel and reduction in the efficiency of feeding in animals and humans (Pitt, 2000). The ear rot caused by *Gibberella zeae* (Schwein) and *Fusarium* species produce mycotoxins in the form of zearalenone that causes estrogenic mycotoxicoses which result in the enlargement of uteri and mammary glands, vulva swelling, vaginal prolapse, and atrophy of the testes, esophageal cancer and neural tube birth defects (Clements *et al*., 2004; Nordy *et al*., 2007). Severity of *Fusarium* ear rot of maize is correlated to Thrips population, drought stress and delayed planting dates. However, hybrids of maize that are resistant usually exhibit lower Fusarium ear rot and fumonisin B1 contamination (Parsons and Munkvold, 2010).

Numerous efforts have been tailored towards understanding the causation and mode of transmission of maize fungal infections (Kedera *et al.,* 1999). Other works have focused on the characterizations of the various types of maize ear rots (Amanda, 2013), while some researchers have diverted their interest towards understanding maize defensive mechanisms against ear and kernel rot diseases (Guest and Brown, 1997). All of these efforts were aimed at countering the threat posed to global food security by these pathogens.

Many varieties of maize are susceptible to ear rot fungi that reduce yield, quality and market value of kernels. Losses due to ear rot vary, but can be severe, threatening food security. Although maize ear rot exists in the major maize growing areas in Ashanti Region of Ghana, limited information is available on the types of maize ear rot and the causative agents. Also, the prevalence of maize ear rot and associated factors leading to the rot and subsequent losses are necessary to be identified, so that effective management practices can be instituted. Such interventions will reduce losses and help promote food security.

The main objective of this study was to determine the prevalence of maize ear rot, the causal agents and factors influencing the rot.

The specific objectives of this study were to:

i. determine factors that influence maize ear rot infection in the major maize growing areas in Ashanti Region of Ghana,
ii. assess the prevalence of maize ear rot in the major maize growing areas in Ashanti Region of Ghana,
iii. determine the types of maize ear rot, and
iv. identify fungi associated with maize ear rot in the major maize growing areas in Ashanti Region of Ghana.

CHAPTER TWO

2.0 LITERATURE REVIEW

Maize is one of the most important cereal crops in West and Central Africa. Its role in human diet, animal feed and industries increased tremendously in the later part of the 20th Century. Maize has a relatively short growth cycle, is easy to grow solely or in a mixture with other crops, and its preparation as food is relatively easy (Badu-Apraku *et al.*, 2004).

2.1 Climatic requirements for maize

Maize tolerates a wide range of environmental conditions, but grows well in warm sunny climates with adequate moisture (Purseglove, 1992). The crop is grown in climates ranging from temperate to tropical regions during the period when mean daily temperatures are above 15 °C. Although the minimum temperature for germination is 10 ºC, germination will be faster and less variable at soil temperatures of 16 to 18 ºC. At 20 ºC, maize should emerge within five to six days. The critical temperature detrimentally affecting yield is approximately 32 ºC (du Plessis, 2003).

2.2 Water requirements for maize

Maize is an efficient user of water in terms of total dry matter production and among cereals, it is potentially the highest yielding grain crop. For maximum production, a medium maturity grain crop requires between 450 and 600 mm of water per season, depending on climate. Maize demands maximum moisture during tasselling and silking periods. Favourable water conditions for maize exist when soil moisture is surplus at the roots and total rainfall of at least 400 mm is favourably distributed during the growing season (du Plessis, 2003). The most favourable soil-moisture content for the growth and development of maize and for high yield is 60 to 70 % of field capacity. In drought conditions, the rate of growth decreases, the silking period is retarded and grain filling and formation is significantly reduced, resulting in yield reduction (Raemaekers, 2001).

2.3 Soil requirements for maize

The most suitable soil for maize is one with a good effective depth, favourable morphological properties, good internal drainage, an optimal moisture regime, sufficient and balanced quantities of plant nutrients and chemical properties that are favourable specifically for maize production (du Plessis, 2003). While maize is adapted to a wide variety of soils in the tropics, ranging from sand to heavy clays, most maize is grown on well-structured soils of intermediate texture (sandy loam to clay loams), which provide adequate soil water, aeration and penetrability. In the tropics as whole Maize does well on most soils but less so on very heavy dense clay and very sandy soils. The soil should preferably be well-aerated and well-drained as the crop is susceptible to water logging. The fertility demands for grain maize are relatively high and amount up to about 200 kg/ha N, 50 to 80 kg/ha P and 60 to 100 kg/ha K (FAO, 2013). In general, the crop can be grown continuously as long as soil fertility is maintained (du Plessis, 2003).

2.4 Constraints to maize production

The average yield of maize in developed countries is about 4.9 tonnes per hectare, but production per hectare is still very low in Africa (1.7 tonnes per hectare (FARA, 2009). The low yields of maize in Africa results from the interaction of abiotic factors which include the volume and distribution of rainfall and soil fertility, and biotic factors comprising diseases and insect pests (IITA, 2009). Other biotic and abiotic factors that pose constraints to the production of maize include wind, ultraviolet radiation, and flooding, low nutrients supply to the soil, and the effect of drought and air pollution which is detrimental to the entire environment (Shafiq-Ur-Rehman *et al*., 2005). Some of the constraints are poor management systems and late planting (IITA 2009).

2.5 Abiotic factors that facilitate occurrence

The major abiotic factors that cause maize ear rots include water, temperature and soil types.

2.5.1 Water

The moisture content of maize increases the metabolic activities of maize ear rot pathogens on the field and during storage. Splashing water facilitates the transportation of inocula from one host to another. Water helps in the germination and infection of the pathogen during its time of attachment on the host (Vincelli, 1997). The pathogen requires water in order to metabolize its host body tissues and cause disease. The metabolic activities of the pathogen increase when farmers carry out late harvesting and the rain comes upon the maize crop in the field. This practice by farmers can lead to massive ear rot infection and losses.

2.5.2 Temperature

Temperature increases the moisture content of maize in storage facilities, thereby enhancing the metabolic activities of ear rot pathogens. For many pathogens, warm temperature facilitates rapid infection on maize both on the field and in storage. *Diplodia* ear rot requires wet condition and moderate temperature for infection to occur (Mosanto, 2012).

2.5.3 Types of soil

All soil types support maize growth and subsequently contribute to maize ear rot infection. Soil contributes to maize ear rot by harbouring the pathogen in it. The soil serves a source of inoculum, awaiting the appropriate environmental conditions to infect the kernels and cause ear rot. Fungi such as *Fusarium, Gibberella, Aspergillus, Penicillium, Diplodia* and *Cladosporium* spp. have been implicated as field fungi that cause severe infection during drought stress at the time of silking and warm temperature. The severity of these fungal infections also depends on the damage caused by birds, hail and insects (Sweet and Wright, 2008).

2.6 Biotic factors that cause ear rots of maize

The major biotic factors that cause maize ear rots include insects, maize earworms and birds.

2.6.1 Insects and Maize Earworm, *Helicoverpa zea* (Boddie)

Insects serve as vectors of ear rot pathogens and create wounds for rot infections. The insect damage is caused to the ears of the maize and it predisposes the kernels to ear rot infection (PAS, 2010). Insects cause damage to maize and predispose the maize cobs to ear rot infection. Insects that are associated with maize ear rots are: The European corn borers, corn ear worms, the nitidulid beetle complex and Thrips (Dowd, 1998). Thrips damage plant tissues by the pierce and suck as well as the punch and suck method which damages the epidermal tissue and the subsequent consumption of sap (Hunter and Ullman, 1992).Thrips cause disruption of the pericarp which lead to fungal infection and reduce yield to the crop (Ferrar and David).

The maize earworm, also known as the tomato fruit worm and the cotton bollworm, feeds on a number of crops including maize. Losses due to maize earworm in field maize have been estimated at 2.5 % annually, with losses in the southern United States ranging from 1.5 to 16.7 % (Cook *et al*., 2004). Losses may be as high as 50 % (Cook and Weinzierl, 2004). The larvae of ear worms attack the buds or central shoots of young maize by feeding on the tender, unfolding leaves, or later, on the tassels. Serious damage occurs when earworms attack maize ears. They may penetrate down the ear, and often eat all the kernels and leave moist castings from their feeding. These castings, frequently visible at the tip of the ear, render the corn unsalable (Mayer *et al*., 2003). The associations between these insects and maize diseases result from several types of host-insect-pathogen interactions.

European maize borer larvae carry spores of *Fusarium* species from the plant surface to the surfaces of damaged kernels (Sobek and Munkvold, 1999) or to the interior of stalks, where infections are initiated. Viable spores can be found externally, internally, and in the frass of European maize borer larvae. Similar relationships exist between maize earworm or southwestern maize borer and *Fusarium* or *Aspergillus* species (Dowd, 1998). A second type of interaction is the formation of entry wounds for the fungi when larvae feed on stalks or kernels. Even when the larvae do not directly carry the fungi into the stalks, spores subsequently deposited on the wounded tissue are very likely to infect the plant.

2.6.2 Birds

It is common for birds to be attracted to only one of several maize hybrids in a field or to one field over another adjacent one. The reasons for this are not clear, but probably related to slight differences in kernel maturity or other kernel characteristics between hybrids. Bollinger and Caslick (1985) indicated that kernel maturity (as measured by date of silking) was the most important factor in determining the level of blackbird damage to maize. The second most important factor was the peak population level of maize rootworm beetles. Within a field, the degree to which the husk leaves extended beyond the tip of the ears was strongly correlated with the severity of damage (Caslick, 1985). Bollinger and Caslick (1985) indicated that an average of 10 % maize ear damage throughout a field was associated with an estimated 5,000 birds. Such bird feeding damage predisposes the ears to the development of various ear moulds and rots, some of which may, subsequently, lead to the development of mycotoxins (Voight, 2008 Woloshuk, 2001).

2.7 Occurrence of maize ear rots

Ear rots occur worldwide, wherever maize is grown, reducing yield and quality (Kommedahl and Windals, 1981). High levels of ear rot infection and mycotoxins accumulation have been reported in pre-harvest maize in Europe, North and South America, and Asia (Chapman and MacDonald, 1997; Viger *et al*., 1997; Logrieco *et al*., 2002), South Africa (Rheeder *et al*., 1992), East Africa (Bigirwa *et al*., 2007) and (Kedera *et al*., 1999; Kapindu *et al*., 1999). The ear rot fungi can occur where the environment is favourable. Cool and dry weather favours the infection and growth of Diplodia ear rot. The fungi may grow favourably in storage and produce mycotoxin if adequate precautions are not taken (Alison, 2009).

2.8 Types of maize ear rots

There are twelve types of maize ear rots occurring worldwide (IPM, 1991). The most prevalent species include Penicillium, Diplodia, Fusarium, Gibberella, Aspergillus and Trichoderma ear rots.

2.8.1 Penicillium ear rot

Penicillium ear rot (Plate 1) is most commonly caused by *Penicillium oxalicum* (Springer), although other *Penicillium* species are also involved in the disease complex (CIMMYT, 2004). The disease is common wherever maize is grown although incidence is higher in warmer climates. *Penicillium* ear rot can be distinguished from other ear rots by its distinctive symptoms. Growth of *Penicillium* species on culture is filamentous, rapid, flat, and cottony in texture. Colonies are initially cottony-white but become blue-green as colonies mature and sporulate (Sweets *et al*., 2008). Penicillium ear rot predominantly occurs on ears that have been damaged mechanically or by insect injury. It is particularly common in fields that are infested with insect borers that attack the stem. The disease can also arise where maize is stored at high moisture levels, particularly if ear rot is observed prior to harvest (Sweet and Wright, 2008) Humidity above 80 % after grain fill leads to increased disease severity.

Plate 1: Penicillium ear rot (Source: www.pioneer.com)

2.8.2 Diplodia ear rot

The fungal pathogen that causes Diplodia ear rot is *Stenocarpella maydis* (Berkeley). (syn. *Diplodia maydis* (Berk.) Sacc. Maize is the only host for this pathogen (DuPont Pioneer, 2010). *Stenocarpella maydis* survives on diseased stalk and ear tissues that have not been buried. The fungus reproduces on the plant debris and produces spores that are moved by rain and wind to the new crop. The fungal spores land on the plant and commonly infect at the base of the ear if sufficient water is available (Malvick, 2001). *Diplodia* ear rot can be recognized as a thick mould that usually starts at the base of the ear. Later the white mould changes to a greyish-brown growth over the husks and kernels. The entire ear may shrink, and the infected kernels appear glued to the husks. Infected ears are very lightweight and may be totally rotted. In some cases, the mould may be detected at the tip end of the ear. A specific characteristic of *Diplodia* ear rot is the appearance of raised black fruiting bodies of the fungus on mouldy husks or kernels (Ohioline.osu.edu/ac-fact/0046.pdf). However, these black bodies usually form later in the season but if infection occurs early, then the entire ear may be covered with mould. If infection occurs several weeks after silking, then only a portion of the ear may be affected (Plate 2). Later infections may result in only a fine web of fungal growth appearing on kernels (http://ohioline.osu.edu/ac-fact/0046.html). Although a key to the disease cycle for Diplodia ear rot is movement of the pathogen from infested corn debris on the soil surface to growing plants and vice versa, infection appears to be highly dependent on wet weather for two to three weeks after flowering (Malvick, 2001). Another factor that contributes to this disease is the amount of *Diplodia* stalk or ear rot in the previous crop and the quantity of infested debris that remains on the soil surface. Some maize hybrids are more resistant to Diplodia ear rot than others, which may affect severity of this disease as well as the number of spores that are produced on infected residue (Malvick, 2001). Planting resistant hybrids is the most effective way to control Diplodia ear rot. Crop rotation and tillage can reduce the occurrence of the disease by reducing fungal levels in the field. Farmers are advised to dry harvested grain to 15% and below to prevent further mould growth in storage. It is also advisable not to mix mouldy grain with clean grain prior to using it as feed to prevent problems with livestock (Malvick, 2001).

Plate 2: Diplodia ear rot (Source: www.pioneer.com)

2.8.*3* Fusarium ear rot

Fusarium ear rot (Plate 3) is the most common fungal disease on maize ears (PAS, 2010). It is caused by several species of *Fusarium*. Often, the decay begins with insect-damaged kernels (Munkvold, 2001). Usually, it does not involve the whole ear. Symptoms of Fusarium ear rot include a white to pink; cottony mould that can begin anywhere on the ear but often begins with insect damage or split kernels. Usually, the entire ear does not rot and affected kernels are scattered across the ear. Infected kernels usually are tan or brown or have white streaks. The fungus produces the mycotoxin, fumonisin (Vincelli and Parker, 2002). In severe infections, the ears may be completely spoilt by the fungus, leaving lightweight husks cemented to the kernels by mycelia (Munkvold, 2001).

Disease may be more prevalent with hot and dry weather. Fusarium ear rot is more common in fields that have a high incidence of insect damaged ears and where previously infected maize residue is present (Corn Field Guide, 2009). Fusarium ear rot is more common in non-BT maize because of greater insect damage to ears. Early plantings usually escape serious injury and there are no registered fungicides for this disease (Corn Field Guide, 2009).

Plate 3: Fusarium ear rot (source: www.pioneer.com)

2.8.4 Gibberella ear rot

Gibberella ear rot is caused by the fungus *Gibberella zeae* (Schwein.:Fr.) Petch (anamorph: *Fusarium graminearum* Schwabe). The fungus typically infects via the silk channel, causing a pinkish-white mould to develop at the tip of the ear. Cool, wet weather during and after silking provides optimal conditions for the development of ear rot. During infection and colonization of the ear, the fungus produces several mycotoxins, including deoxynivalenol (DON) or vomitoxin. As a result, high levels of Gibberella ear rot severity and mouldy grain are usually accompanied by high levels of vomitoxin (Willyerd *et al*., 2010). This disease is most readily identified by the red or pink colour of the mould starting at ear tip (Plate 4). Mould may be very pale in some cases, causing it to be confused with other ear rots. *Gibberella* almost always begins at the surface ear tip and progresses from there (Pioneer, 2014). Perithecia, or black fungal fruiting structures, may be lightly attached to kernel. Cool, wet weather, within first 21 days after silking, favours the development of this disease. Continued development of the mould also depends on subsequent cool, wet weather. Optimum temperatures for disease development are 18-21 °C (Woloshuk *et al*., 1997).

Plate 4: Gibberella ear rot at the maize ear tip (Source: www. pioneer.com)

2.8.5 Aspergillus ear rot

This disease is caused by *Aspergillus flavus* (Link: Fr.). It is most common under drought conditions, high temperatures (27-38 ^{o}C) and high relative humidity (85 %) during pollination and grain fill (Pioneer, 2010). Maize ears are damaged by insects and birds that crack the kernels and predispose the grains to infection (Munkvold, 2001). Circumstances that favour mouldy growth may also favour mycotoxin production although mould growth can occur with little or no mycotoxin production. *Aspergillus* spores are produced on crop residue, soil surface and discarded kernels. *Aspergillus* can occur on many types of organic material, including forages, cereal grains, food and feed products and decaying vegetation. Partially or completely buried infected residue reduces disease inoculum and incidence. Fungal spores over- season on plant residue. *Aspergillus* can also produce specialized survival structures that enable it to survive in the soil for extended periods (Pioneer, 2010). *Aspergillus niger (*Tiegh*)* appears as a black mould (Plate 5) on infected kernels (Palencia *et al*., 2010). *A. flavus* Link is a greenish-yellow mould growing on damaged kernels. *A. glaucus* Michele is a greenish mould (Jacobsen, 2007). Infection of maize by *A. flavus* and consequent disease development is favoured by hot (>30 ^{o}C$^{)}$ dry conditions at pollination and during grain fill (Zummo and Scott, 1992).

Yellow brown silks are most susceptible to infection. Fungal spores become airborne and can infect kernels by growing down the silk channel when silks are yellow-brown and still moist. Infection is most common through kernel wounds caused by several types of insects. Spores landing on the silks germinate, rapidly grow down the silk and colonize the surface of the developing kernels (Zummo and Scott, 1992). Around physiological maturity, when moisture content drops to around 32 %, the fungus starts to colonize the internal tissues of the kernels, and it continues to grow until moisture content is around 15 % (Robertson, 2012).

Plate 5: Aspergillus ear rot (source: www.pioneer.com)

As a management practice, it is advisable to plant adapted hybrids. Hybrids containing a Bt-gene for above-ground insect protection help reduce damaged kernels and fungal spore entry points (Pioneer, 2010). Hybrids that perform well in drought conditions generally have lower *Aspergillus* concentrations than hybrids that yield poorly in drought conditions. Damage from ear feeding insects can be minimized by using appropriate field treatments (Pioneer, 2010). In storage, control is by drying maize to moisture content below 15 % as soon as possible after harvest.

2.8.6 Trichoderma ear rot

Trichoderma ear rot (Plate 6) is one of the less common ear rots of maize in Kentucky, USA (Kentucky Pest News, 2011). However, it is possible to occasionally see severe outbreaks of this disease. This ear rot produces abundant growth of green fungal material between kernels, often involving much of the ear. Sometimes, in severely affected ears, kernels germinate within the husk. Not all greenish moulds on rotted maize kernels are caused by T*richoderma*. However, *Trichoderma* can be commonly recognized by dark green to bluish-green fungal growth between kernels, often involving large areas of the ear (Vincelli, 2011). Typical symptoms include a dark green fungal growth on and between husks and kernels, often involving the entire ear (Plate 6). Fungal disease of ears is usually associated with injury to the developing ear, including damage from bird or insect feeding or other mechanical injury (Munkvold, 2001). For this reason, damage is not found on every ear, but rather, is usually more scattered within a field (Pioneer, 2012).

Plate 6: Trichoderma ear rot (Source: www.pioneer.com)

2.8.7 Maize anthracnose

Maize anthracnose (Plate 7) is caused by *Colletotrichum graminicola* Politis. The pathogen causes damage to plant roots, rot of stems, wilt of leaves, and ear rot of kernel and infection of seeds (Sukno *et al*., 2008). The pathogen is favoured by high air humidity and it causes damage to crops such as fruit trees, legumes, cereals and vegetables. *Colletotrichum* causes anthracnose that is characterized by sunken necrotic tissue that produces masses of orange or reddish conidia. The anthracnose of maize causes serious yield loss if the fungus covers 40 % of the leaf surface (University of Delaware Fact sheets, 2014). *Colletotrichum graminicola* exhibits biotrophic growth by spreading to adjacent epidermal cells after infection and then after 48 to 72 h the fungus switches to necrotic growth by colonizing the inter-and intra-cellular spaces of the tissue, resulting to the death of the host cells (Bergstrom and Nicholson, 1999).

Plate 7: Maize Anthracnose (Source: www.pioneer.com)

2.8.8 Curvularia ear rot and leaf spot

Curvularia leaf spot of maize is caused by *C. lunata* Wakker. The fungi causing the leaf spot are opportunistic and are characterized by small necrotic or chlorotic spots with light coloured halo lesions with a diameter of about 0.5 cm when the disease is fully developed (The CIMMYT Maize Program, 2004). The Curvularia leaf spot is prevalent in hot, humid maize areas that can cause tremendous damage to maize growing areas and there is no information on whether the fungus causes ear rot but is associated with ear rot as it has been isolated from cultural media. *Curvularia* race 1 causes ear rot and produces an oval, zonate, brownish lesion on all parts of the plants. Curvularia ear rot (Plate 8) causes the maize ear to rot and turn black (De Leon, 1984).

Plate 8: Curvularia ear rot (source: www.pioneer.com)

2.9 Management of maize ear rots

Many management practices can be used to reduce maize ear rot infection: Growing of resistant varieties is the most preferred. Inbred lines differ in their resistance to the various ear- and kernel-rotting fungi and transmit their reaction to their hybrid combinations. No inbred line or hybrid, however, is completely resistant to all ear-rotting fungi. Hybrids with poor husk are susceptible to infection by certain ear- and kernel-rotting fungi (Malvick, 1991).

Maintenance of balanced soil fertility based on the results of a soil test is recommended. There is a need to irrigate, where possible, during extended droughts. Control of maize earworms and maize borers, where practical, by timely applications of insecticides, is recommended. Maize can be harvested soon as moisture levels permit. Maize ear and shelled grain can be stored at the recommended levels of moisture content below 18 % for ears and 13 to 15 % for shelled maize. Where possible, the grain can be aerated to maintain a uniform temperature of 4 to 10 ^{o}C throughout the bulk. Only properly cleaned grain should be stored in a store that has first been thoroughly cleaned of debris. This practice will limit the development of ear and kernel rot as well as storage rot fungi (Mills, 1989).

2.10 Factors influencing ear rot / infection

There are a number of factors that influence ear rot. Some of the main factors include moisture content, temperature, storage and humidity.

2.10.1 Maize moisture content

The amount of moisture content of maize determines the level of growth of mould on the grain and the subsequent production of toxins. The physiological properties of the maize ear rot pathogen determine the moisture content of the maize upon which it thrives properly. Gibberella ear rot mould will develop when the moisture content of the maize is above 22 % (Woloshuk *et al*., 1997).

2.10.2 Storage environment

Under storage conditions, maize seeds that are not conditioned and their moisture content are above 15% can development maize ear rot infection (Czember, 2010). Storage conditions such as high relative humidity and insufficient aeration can enhance the development of ear rots in storage. Poor facility that does not control or limit the movement of insects can transport the inoculum of the ear rot pathogen in storage and cause ear rot infection. The risks of maize ear rot pathogen can increase if unclean bins are used in storage facilities. Inappropriate temperatures within the storage facilities can cause the relative humidity to increase, thereby favouring the development of ear rot pathogens. . Poor storage facilities can increase insects' infestation, thereby increasing the moisture content of the maize. This eventually results in damage to the maize cobs in storage facilities (Imura and Sinha, 1989).

2.10.3 Temperature

The temperature that contributes or causes maize ear rots varies according to the types of ear rot fungi involved in the infection of the maize. According to IPM report (1991), maize ear rots prevalence varies according to the amount of rain fall. Diplodia ear rot occurs when the weather is wet and the temperature is moderate; Gibberella ear rot is favored by temperature between 18 to 21 ^{o}C and cool, wet weather. Fusarium ear rot is facilitated by warm weather whereas Aspergillus ear rot is enhanced by temperature between 27-38 ^{o}C with a relative humidity of 85 % (Pioneer. 2014).

2.10.4 Humidity

This is amount of water vapour in the air that contributes to the infectious physiological processes of the ear rotting fungi. However, various ear rotting fungi respond to different relative humidity to infect maize. Aspergillus ear rot occurs at warm temperatures and relative humidity of 85 %. Diplodia ear rot is enhanced by high relative humidity of 85 % during pollination of the maize (DuPont Pioneer Hi-Bred, 2014). Gibberella ear rot and Fusarium ear rots occur at a high relative humidity (Sweets and Wright, 2008). The ear rot caused by *Trichoderma stromaticum* (Samuel and Pardo-Schulti) occurs at a relative humidity of 100% (Sanogo *et al*., 2002).

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Survey: Assessment of farmers' perceptions and management of maize ear rots in the major maize growing areas of the Ashanti region of Ghana

During the survey, farms and warehouses were targeted for sample collection. At the sample collection sites, questionnaires were administered to assess the farmers' perception of maize ear rot and pest management practices, including the use of weedicides, fungicides and insecticides, the farmers' sources of seeds, planting dates, harvesting time, the types of maize cultivars used in their farming systems and the types of intercrops used (Appendix I).

3.2 Sampling and communities

During the major season, a total of 195 maize samples were collected from 39 communities in major maize growing areas of Ashanti Region of Ghana. Five maize cobs were randomly collected from each of the communities in August, 2013. The 39 communities covered 16 metropolis, municipals and districts of Ashanti Region. The municipals and districts were Amansie Central, Ejisu-Juaben, Sekyere East, Sekyere Central, Atwima Nwabiagya, Ejura/Sekyedumase, Atwima Mponua, Sekyere South, Kwadaso sub-Metro, Mampong municipal, Sekyere West, Kumasi Metropolis, Atwima Kwanwoma, Ahafo Ano South, Amansie West and Atwima Foase (Fig. 3.1). The municipals and districts were selected, based on their levels of accessibility and maize production. Each maize sample was placed in a polythene bag sealed and clearly labeled. The samples were then transported to the KNUST Plant Pathology laboratory for analysis.

During the minor season, a total of 100 maize samples were collected from within the 20 sampled communities of the major maize growing areas of Ashanti Region of Ghana. Five maize cobs were randomly collected from each of the communities in January, 2014 as described previously.

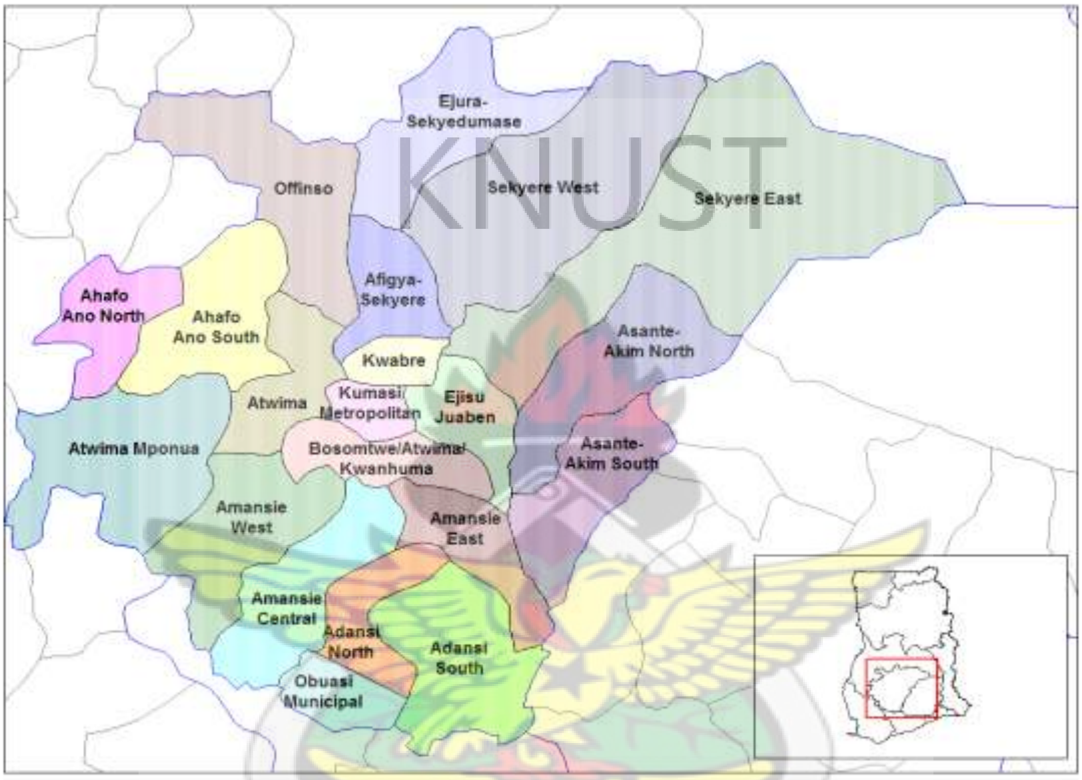

Figure 3.1: Map of Ashanti Region, Ghana, showing the selected metropolis, municipals and districts (Source: www.google.earth)

3.3 Scoring of damage on maize sample

The maize samples were sorted out in groups of five cobs per community and visually observed for bird, insect, and fungal damage. Damage ratings were taken on a scale of 0-5 for all types of damage (Table 3.1).

Table 3.1: Sample design of scoring of damage on maize sample

Damage ratings (Scale 0-5)	Description of damage based on number of cobs
0	No damage on any of the five cobs maize cobs
1	One maize cob damage out of five
2	Two maize cobs damage damaged out of five
3	Three maize cobs damaged out of five
4	Four maize cobs damaged out of five
5	Five maize cobs damaged out of five

3. 4 Moisture content of maize samples

Each of the maize samples from the 39 communities were shelled. A weight of 20 g/com of the shelled maize was taken using an electronic balance and then packaged into an envelope and weighed to obtain 20 g. The moisture content of the various maize samples was determined by drying the samples in an oven at 70 ^{o}C until a constant weight was obtained. The moisture content of the maize was then calculated, using the equation (Chin, 1979) below:

$$\%\ \mathrm{MC} = \frac{\mathrm{Wi} - \mathrm{Wf}}{\mathrm{Wi}}\ \mathrm{x}\ 100$$

Where, % MC is the percentage moisture content of the maize sample, W_i is the initial weight of the sample and W_f in the final weight of the sample after drying.

3.5 Identification of maize ear rot for maize samples collected

The mycological procedures for the identification of maize ear rot fungi involved sterilization of Petri dishes, the maize seeds or grains and the preparation of the potato dextrose agar (PDA), the visual observation of fungal culture growth and the use of the light microscope to observe fungal spores. During the process of identification, a needle dipped into 70 % alcohol was used to pick the fungi growing on the maize kernel and placed on a water mount slide. The slide was then placed on the stage of a microscope for observation and subsequent identification of the fungal spores. The type of fungi identified was based on the shape and size of the spores. The mycelial growth observed after the seven days incubation period on the culture media was followed by microscopic identification. The filamentous hyphae of the fungi were picked with a sterilized needle and placed on a water mount slide. The slide was placed on the stage of the microscope for visualization. The observed fungi were characterized by their morphological structure and the types of spores produced, using the aid of the laboratory resource materials. A laboratory Manual (Mathur and Kongsdal, 2001) was used as a guide to the morphological identification of the fungi.

3.5.1 Sterilization of Petri dishes

The Petri dishes were sterilised in an oven at 160 ^{o}C for three hours. This procedure was to eradicate any pathogen or fungi that might cause contamination of the Petri dishes and cultures.

3.5.2 Sterilization of maize seeds

Samples of 195 maize cobs were tested in 39 replicates of five seeds per plate. The maize seeds samples were surface sterilized to eradicate microbes with 10 % sodium hypochlorite which was prepared by adding 10 ml of concentrated sodium hypochlorite in 90 ml of distilled water. The seeds were sterilized in the bleach for about one minute and then rinsed two times with distilled water for about two minutes and dried with tissue paper.

3.5.3 Preparation of PDA

Potato dextrose agar was prepared by dissolving 39 g in 1 litre of distilled water. The PDA was amended with 500 mg of Chloramphenicol to suppress bacterial contamination. PDA in conical flask stoppered with cotton wool was placed in an autoclave for sterilization at 121 ^{o}C, 0.98 kg/ cm^2 for 20 min. The PDA was allowed to cool and then poured into the sterilized Petri dishes. The PDA in the Petri dishes was then allowed to solidify in the laminar flow cabinet.

3.6 Plating of the sterilized maize seeds on the PDA.

The sterilized maize seeds were plated, five seeds per plate. The forceps used to plate maize seeds were sterilized with ethanol and lamp flames containing methanol to avoid contamination. The media along with the plated seeds were allowed to stay for seven days to enhance the sporulation of the fungi.

CHAPTER FOUR

4.0 RESULTS

This chapter presents the results of data collected from field surveys to assess farmers' perceptions on the occurrence of maize ear rots and management of the disease by farmers. It also covers laboratory analyses to identify the types of maize ear rots fungi and their prevalence in the study area.

4.1 Surveys: Assessment of Farmers' perceptions and management of maize ear rots in the major maize growing areas of Ashanti region of Ghana

4.1.1. Socio-demographic characteristics of respondents

There was a dominance of female farmers (70 %) as against male farmers (30 %) out of a total of 44 respondents (Table 4.1). The results showed that majority (43 %) of the respondents were within the age range of 41 to 54 years, 39 % were in the age range of 25 to 40 years, while 16 % were in the range of 55 to 70 years. The minority of the respondents (2 %) were above the age of 70 years (Figure 4.1). Additionally, the majority (77 %) of the farmers interviewed had primary school education and the minority (5 %) had education up to tertiary levels (Figure 4.2). About 9 % had up to secondary school education and a small number did not have formal education (Figure 4.2).

Table 4.1 Sex of maize farmers interviewed in the major maize growing areas of Ashanti Region, Ghana

Sex	Percent farmers
Male	30
Female	70
Total	100

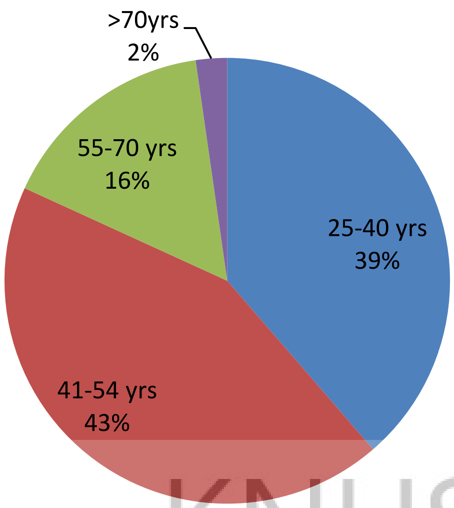

Figure 4.1: Age distribution of maize farmers sampled from the Ashanti Region

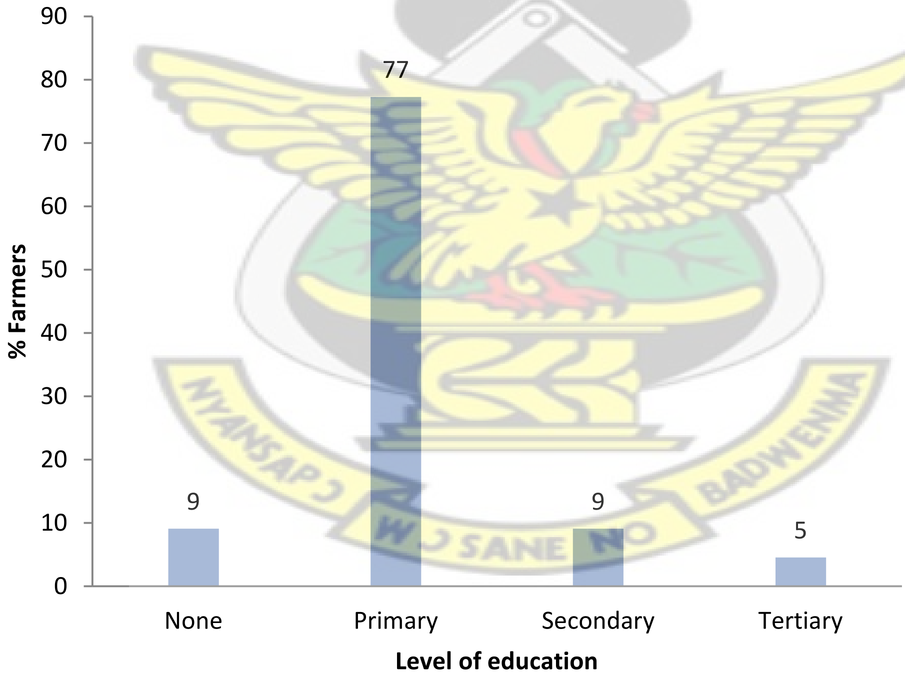

Figure 4.2: Percentage distributions of respondents based on level of education in major maize growing areas of the Ashanti Region of Ghana

4.1.2. Farming practices of maize farmers in Ashanti Region

Experience in years of cultivation of maize amongst farmers varied. The results showed that 43 % of the farmers interviewed had about 20 years or more experience of cultivating maize; 20 % between five and 10 years of experience; while 14 % had between 11 to 15 and 16 to 20 years of experience, respectively. The rest of the respondents (9 %) had five years or less experience of cultivating maize (Figure 4.3).

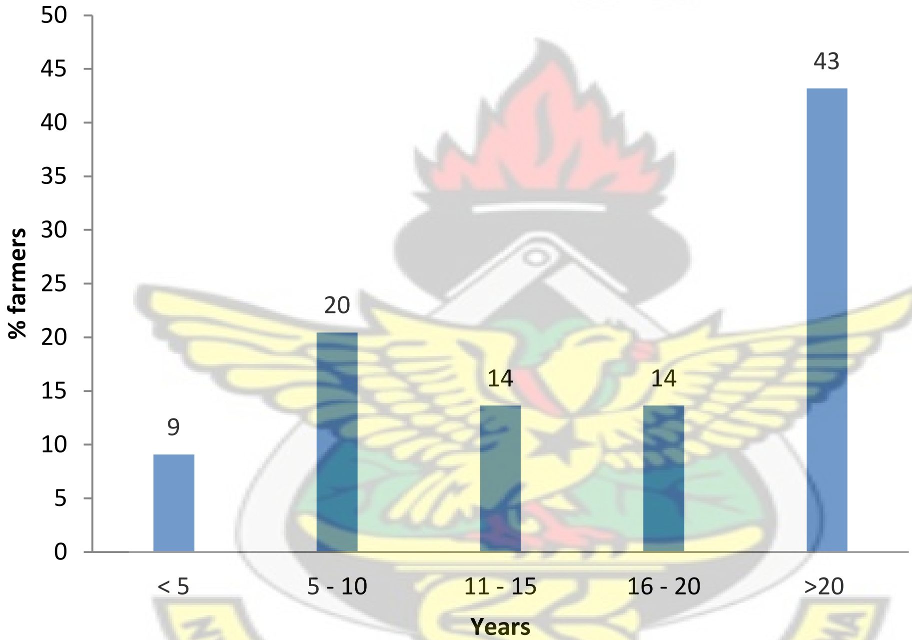

Figure 4.3: Experience of respondents in maize cultivation in Ashanti Region of Ghana

Most of the farmers (48 %) obtained their seeds from the Ghana Seed Company, and about 32 % used their own seed stock (Fig. 4.4). About 11 % of the farmers obtained their seeds from commercial farmers; 5 % from the Ministry of Food and Agriculture (MoFA) and the minority of the farmers obtained theirs from friends and marketers (Figure 4.4). The most commonly cultivated maize varieties in Ashanti Region of Ghana included Obaatampa (59 %), being the most dominant, yellow maize (18 %) and other local maize (23 %) varieties

(Figure 4.5). 66 % of the farmers planted their maize seeds in the month of April; 20 % in March and 7 % each in the months of January and May (Figure 4.6).

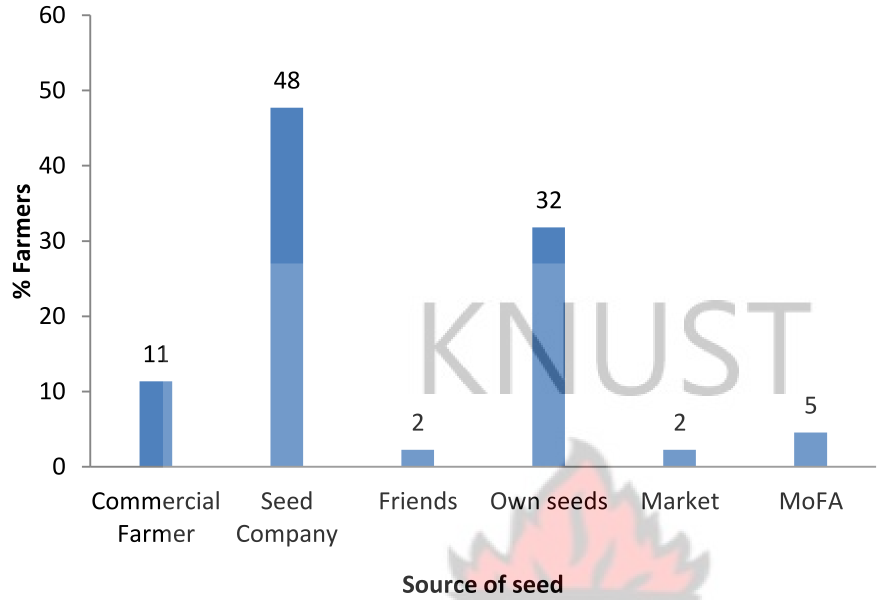

Figure 4.4: Sources of maize seeds for cultivation

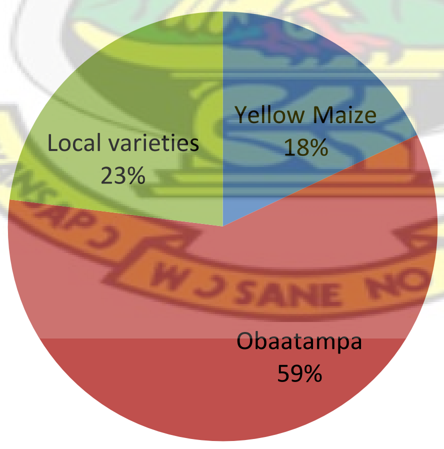

Figure 4.5: Percentage maize varieties cultivated in Ashanti Region of Ghana

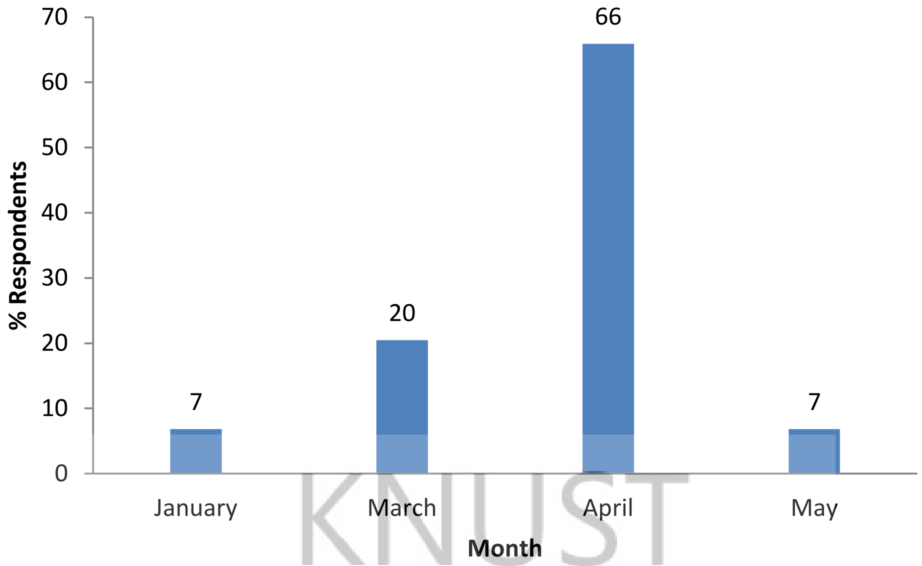

Figure 4.6: Maize planting periods by the respondents

Most (61 %) of the farmers interviewed chose three months as the ideal length of time required for the maturity of the maize; 16 % chose two-and-a-half months, 5 % chose two months, while 11 % chose four months. The minority (2 %) chose five months as the length of time required for the maturity of the crop (Figure 4.7). The majority (84 %) of the respondents observed symptoms of ear rots at the maturity of the crop, 9 % observed symptoms at harvest delay and the minority (7 %) observed symptoms during the rainy season (Figure 4.8). About 13 % of the respondents observed ear rot during both major and minor seasons, 39 % during the minor season, and 48 % experienced ear rot during the major season (Figure 4.9).

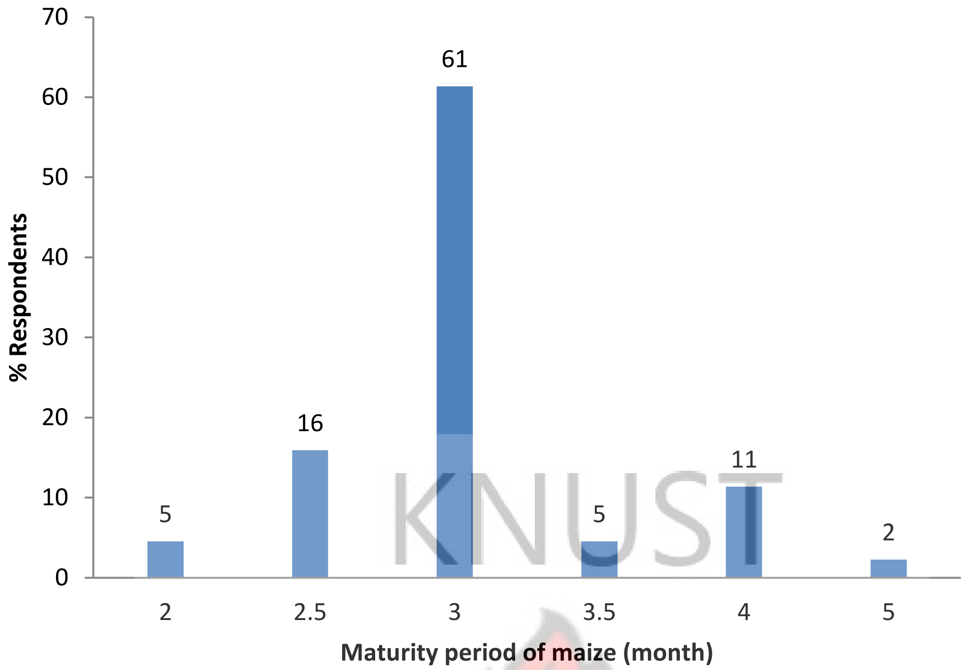

Figure 4.7: Maturity period of maize according to respondents

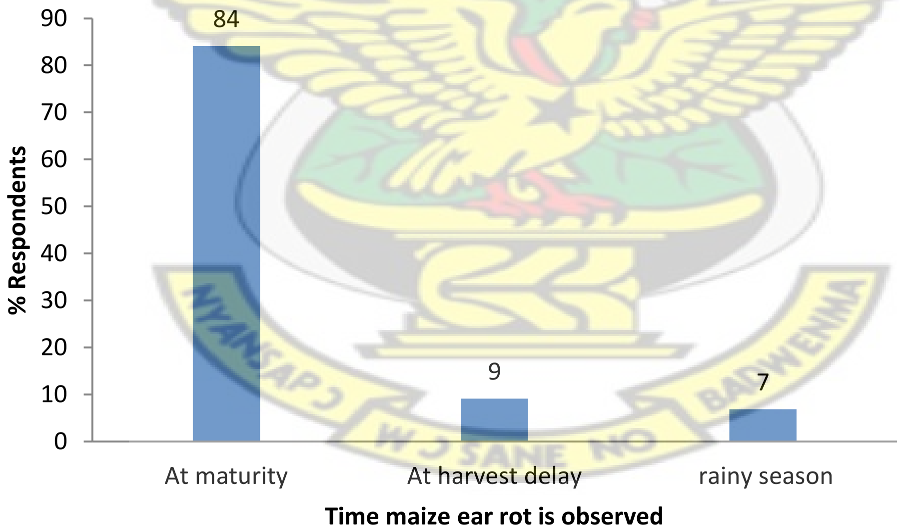

Figure 4.8: First observation of maize ear rots by respondents

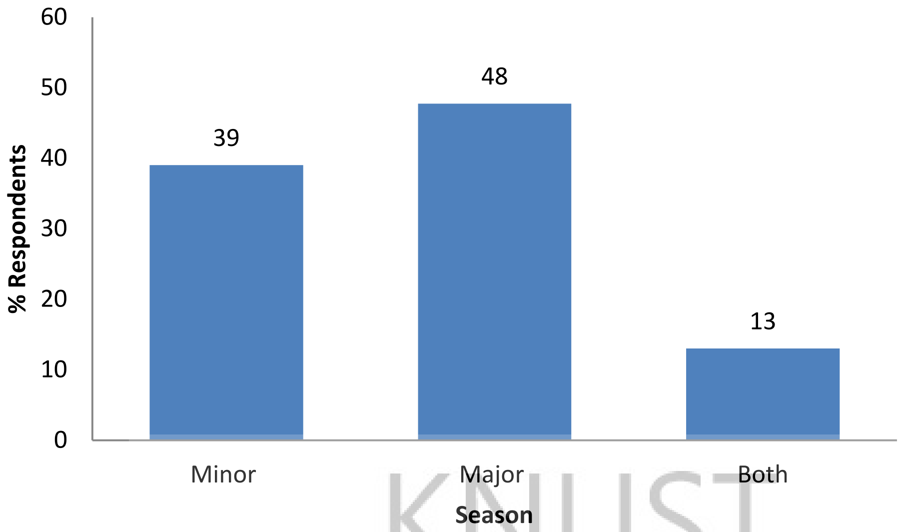

Figure 4.9: Seasonal observation of maize ear rot by respondents

4.1.3. Management of maize ear rots by farmers in the Ashanti Region

The farmers used different methods to control maize ear rots. Out of the 44 respondents, about 11 % used removal of debris, 14 % applied chemicals, 27 % burn their debris, and 18 % do not control the disease and about 30 % use sun drying (Figure 4.10). The results show that majority of the farmers (68 %) had no prior knowledge of any fungicide. Roundup (21 %) appears to be the most popular chemical, followed by Karate (5 %), Paraquat (2 %), Actellic (2 %), and Furadan (2 %). All of the chemicals mentioned by the respondents were either weedicides (Roundup and Paraquat) or insecticides (Acetellic, Karate and Furandan). None of the respondents used a fungicide (Figure 4.11).

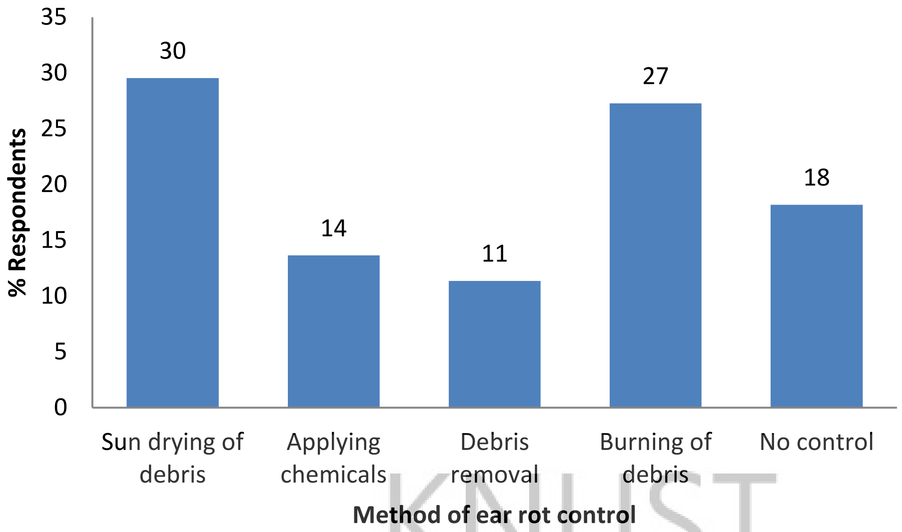

Figure 4.10: Types of management methods used to combat maize ear rot by respondents

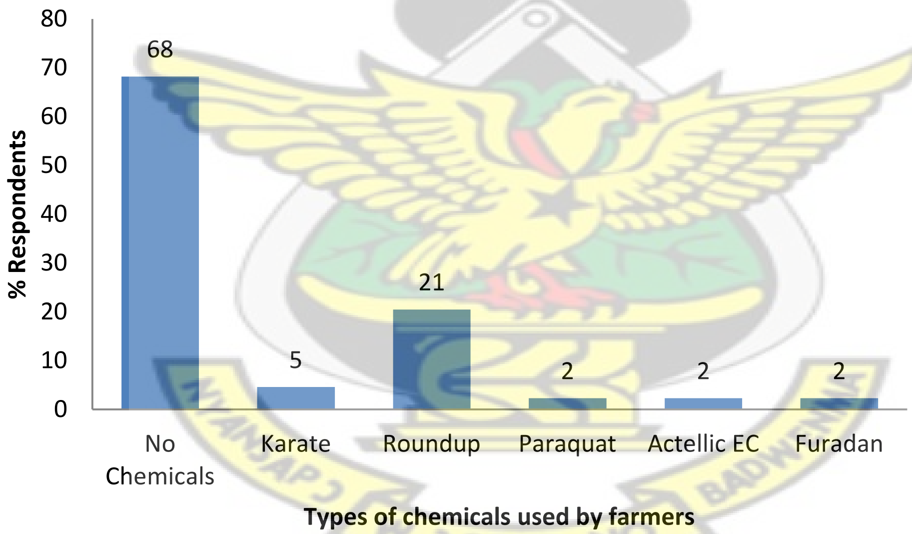

Figure 4.11: Types of chemical known to farmers

4.1.4 Maize cropping system used by farmers in Ashanti Region

The majority of the farmers interviewed (32 %) used cassava as an intercrop with maize and 11 % each used cocoyam or legumes (Figure 4.12). The results also showed that 21 % of the respondents used Plantain as an intercrop, 7 % used cocoa and 5 % used yam. A small number of the respondents (2 %) used citrus as an intercrop with maize while 11 % practiced monocropping system (Figure 4.12).

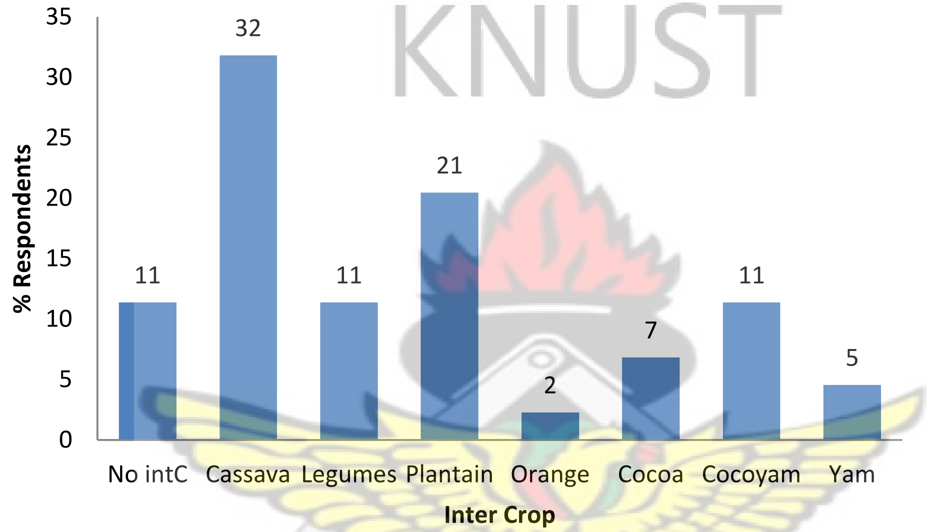

Figure 4.12: Types of intercrop in maize cropping system in the Ashanti Region

4.2 Types of fungi isolated from maize ear rot sampled during the major and minor seasons

The types of fungi isolated from maize ear rot sampled during the major season from March to August 2013 are shown in Figure 4.13. A total of seven fungi in six genera were isolated during this period. The percent prevalence of each fungus is shown in the Figure 4.13. The fungi occurred in the order *A. flavus* > *Colletotrichum* sp. > *Trichoderma* sp.> *Fusarium* sp. = *Aspergillus niger*> *Penicillium* sp > *Curvularia* sp.

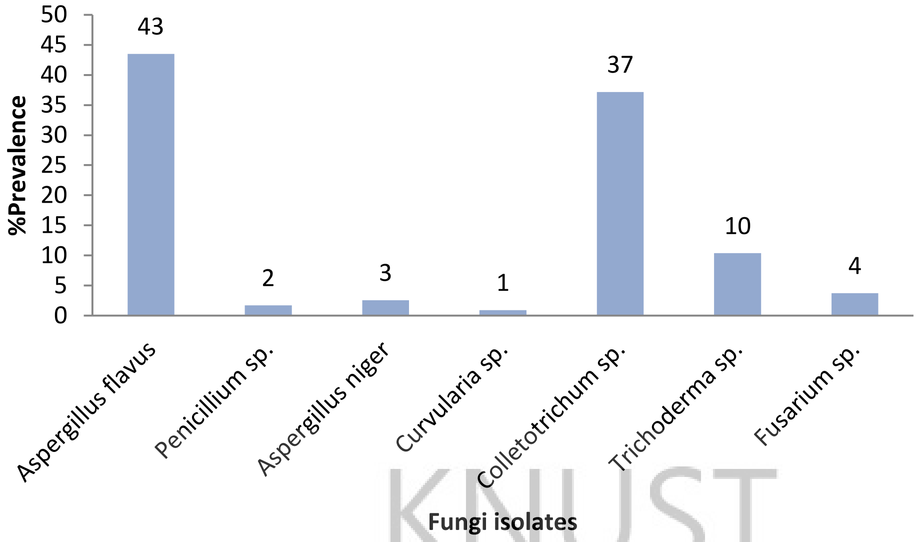

Figure 4.13: Types of maize ear rot fungi isolated during the major season

For the minor season, a total of five fungi in four genera were isolated. The percent prevalence of each fungus is represented in Figure 4.14. The fungi occurred in the order *Colletotrichum* sp. > *A. flavus* > *Trichoderma* sp. > *A. niger* = *Penicillium* sp. The most prevalent fungus identified during the minor season on maize was *Colletotrichum* (Figure 4.14). It was prevalent in communities such as Nsima, Kwadaso F1, Kwadaso F2, Mankraso, CRI-Kwadaso, Asante- Kwadaso, seed compound, KNUST F2, Effiduase-Daako, Afari and Dida and less prevalent in Mampong-Sataso and KNUST F1 while *Trichoderma* was absent in all communities except in Atwima Foase, KNUST F4, and Asante- Mampong-Sataso (Table 4.3).

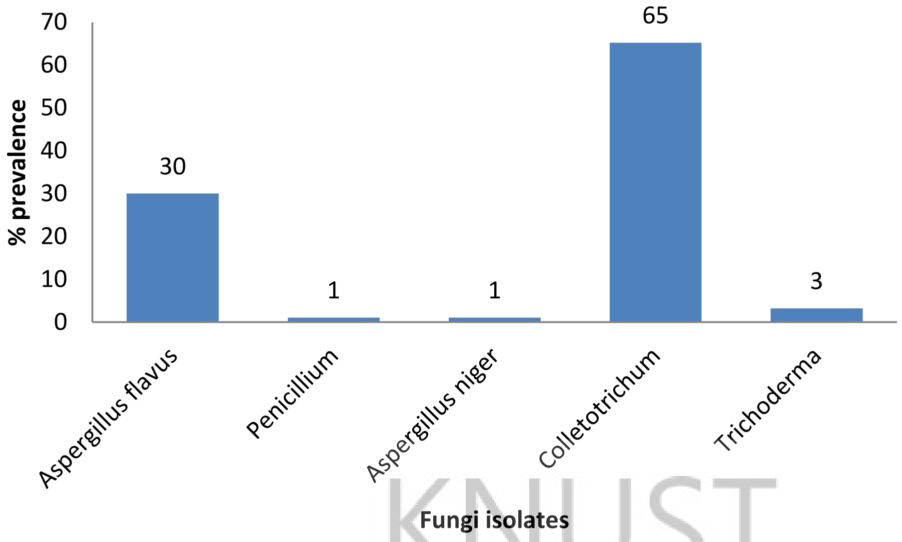

Figure 4.14: Types and percent prevalence of fungi isolated from maize ear rot samples during the minor season

4.3 Prevalence of maize ear rot fungi in the major maize growing areas in Ashanti Region of Ghana

The maize ear rot fungi prevalence per community for the major season is presented in Table 4.2. The most prevalent fungus isolated was *A. flavus* (Table 4.2). It was prevalent in all communities except Naamid Sedi, Kwadaso-Kokode, Kwadaso-Kokode Agriculture Station, Adidwan, Worase- Manpong, Nkrumah Nkwanta-Nyinahini, Trabuom-Tellowi F2 and Betinko. This was followed by *Colletotrichum* sp. and the least prevalent was *Curvularia* species (Table 4.2).

For the minor season, samples were collected from 20 communities and the prevalence of the causal agents of the disease is provided in Table 4.3. The most prevalent fungus isolated was *Colletotrichum* sp. It was prevalent in all communities except KNUST F1, Adidwan and KNUST F4. The second most prevalent fungus isolated during this period was *A. flavus*. It was prevalent in all communities except Mankranso, Effiduase-Dako, Afari, Dida, Ejisu-Donasu, Nyinahini, Atwima-Agogo, KNUST F5 and KNUST F3. The least prevalent fungi during the minor season were *A. niger* and *Penicillium* sp. The former occurred only in Nsima while the latter was found only in Dida (Table 4.3). *Curvularia* species was not isolated during the minor season.

Table 4.2: Fungi prevalence per location for the major season in the major maize growing areas of Ashanti Region

Community	Prevalence of fungi isolated						
	***Trichoderma* sp.**	***Penicillium* sp.**	***Colletotrichum* sp.**	***Aspergillus flavus***	***Aspergillus niger***	***Curvularia* sp.**	***Fusarium* sp.**
Jacobu MOFA	0	0	0	4	0	0	0
Jacobukrom	0	0	0	5	0	0	0
Kwaso (Ejisu Juaben)	0	0	3	4	0	0	0
Akuakrom	0	0	0	5	0	0	0
Deyaasi-Bekwai	0	0	4	4	0	0	0
Ejisu Donasu	0	0	2	3	0	0	0
Juaben	0	0	0	5	4	0	0
Ejisu Juaben-Yaw Nkrumah	0	0	3	4	0	0	0
Yaw Nkrumah-Ejisu juaben F2	0	0	0	3	4	0	0
Senchi (Effiduase)	0	0	0	4	1	0	0
Daako (Effiduase)	0	0	0	5	0	0	0
Odurokrom	0	0	0	5	0	0	0
Apimaso (Effiduase)	0	0	0	4	0	0	0
MOFA (Effiduase)	0	0	1	5	0	0	0
Naamid Sedi	5	0	5	0	0	0	0
Dida	0	0	1	3	0	0	0
Bonwire	0	0	4	2	0	0	5
Atwima Agogo	5	0	5	4	0	0	0
Ejura	5	0	0	4	0	0	5
Nyinahini	2	0	5	5	0	0	0
Agona-Jamasi	5	0	0	4	0	0	0
Kwadaso-Kokode	5	0	5	0	0	0	0
Kwadaso-Kokode Agric. Stat.	0	2	5	0	0	0	0
Adidwan-F2	0	0	5	0	0	0	0
Kumso-Mankraso	0	0	5	3	0	0	0
Trabuom F3	0	0	2	3	0	0	0
Bosom-Kyekye	0	0	3	2	0	0	0
Atwima Foase no.2	0	0	0	5	0	0	0
Worase Manpong	0	0	4	0	0	0	3
Trabuom F1	0	0	2	3	0	0	0

Table 4.2: Fungi prevalence per location for the major season in the major maize growing areas of Ashanti Region

Community	Prevalence of fungi isolated						
	***Trichoderma* Sp.**	***Penicillium* Sp.**	***Colletotrichum* Sp.**	***Aspergillus flavus***	***Aspergillus niger***	***Curvularia* Sp.**	***Fusarium* Sp.**
Sataso-F1	0	0	4	4	0	0	0
Sataso-Manpong	0	4	5	3	0	0	0
Nkrumah Nkwanta-Nyinahini	4	0	1	0	0	0	0
Afari-Nyinahini road	0	0	5	3	0	0	0
Trabuom	0	0	4	1	0	0	0
Trabuom-Tellowi-F2	3	0	2	0	0	0	0
Ejisu-Juaben Nyenkrom	0	0	5	3	0	0	0
Adidwan F1	0	0	1	3	0	0	0
Betinko	2	0	4	0	0	0	0
KNUST F1	0	0	5	3	0	0	0
KNUST F2	0	0	5	4	0	3	0
KNUST F3	0	0	5	3	0	0	0
KNUST F4	0	0	4	4	0	0	0
KNUST F5	0	0	5	2	0	0	0
Total	**36**	**6**	**129**	**151**	**9**	**3**	**13**

Table 4.3: Fungi Prevalence per location for the minor season in the major maize growing areas of Ashanti region

	Prevalence of fungi isolated				
Communities	***Aspergillus flavus***	***Colletotrichum* sp.**	***Trichoderma* sp.**	***Penicillium* sp.**	***Aspergillus niger***
KNUST F1	4	0	0	0	0
Nsima	3	3	0	0	1
Kwadaso F1	2	3	0	0	0
Kwadaso F2	2	5	0	0	0
Mankranso	0	5	0	0	0
CRI-Kwadaso	1	4	0	0	0
Seed CPD.	1	3	0	0	0
KNUST F2	2	3	0	0	0
Effiduase-Dako	0	5	0	0	0
Afari	0	3	0	0	0
Dida	0	4	0	1	0
Manpong-Sataso	4	1	1	0	0
Ejisu-Donasu	0	5	0	0	0
Adidwan	2	0	0	0	0
Atwima-Foase	2	4	1	0	0
Nyinahini	0	4	0	0	0
Atwima-Agogo	0	3	0	0	0
KNUST F5	0	2	0	0	0
KNUST F3	0	3	0	0	0
KNUST F4	4	0	1	0	0
Total	**27**	57	**3**	**1**	**1**

4.4 Insect and bird damage on maize samples from the major maize growing areas in Ashanti Region

The occurrence of maize ear rots can be facilitated by several biotic and abiotic factors. Insects' and birds' damage are biotic factors that influence maize ear rots. The amount of insects' and birds' damage on the samples collected during the major season is presented in Table 4.4. Insect damage was recorded on all cobs sampled from Jacobu MoFA, Daako-Effiduase, Akuakrom, MOFA-Effiduase, Naamid Sedi, Dida, Nyinahini, Kwadaso-Kokode, Kwadaso-Kokode Agriculture station, Adidwan-F2, Kumso-Mankraso, Atwima Foase no. 2, Worase Mampong, Sataso- Mampong, Nkrumah Nkwanta-Nyinahini, Afari-Nyinahini, Trabuom-tellowi F2, Ejisu Juaben- Nyenkrom, Adidwan F1, Betiko, KNUST F1 and KNUST F4. The least insect damage was recorded on cobs sampled from Denyasi-Behwai road and Ejisu-Juaben-Yaw Nkrumah. There was no insect damage on any of the five cobs sampled from Kwaso-Ejisu-Juaben. The most bird damage per cob was recorded on samples from Daako-Effiduase. No bird damage was recorded on samples from Deyasi-Bekwa, Senchi-Effiduase, Oduokrom, Trabuom-F2, Bosom-Kyekye, Worase- Manpong, Afari-Nyinahini, Adidwan F1, Betiko, KNUST F1, KNUST F3 and KNUST F4 (Table 4.4).

The scores for insects and birds damage on samples collected during the minor season are presented in Table 4.5. Insect damage was recorded on all cobs sampled from Nsima. There was no insect damage recorded on cobs sampled from CRI-Kwadaso. The most prevalent bird damage on cob was recorded on samples from Kwadaso F1. No bird damage was recorded on samples from KNUST F1, CRI-Kwadaso, Manpong-Sataso, Adidwan, Nyinahini, Ejisu-Donasu, KNUST F3 and KNUST F4 (Table 4.5).

Table 4.4: Insects and birds damage per five maize cobs collected during the major season in the major maize growing areas of Ashanti Region

Community	No. of maize cobs damaged per pest	
	Insect	Bird
Jacobu MOFA	5	1
Jacobukrom	2	2
Kwaso(Ejisu juaben	0	3
Akuakrom	5	1
Deyasi-Bekwai road	1	0
Ejisu Donasu	2	3
Juaben	3	2
Ejisu juaben-Yaw Nkrumah	1	1
Yaw Nkrumah-Ejisu juaben F2	4	1
Senchi(Effiduase)	4	0
Daako(Effiduase)	5	4
Odurokrom	3	0
Apimaso(Effiduase)	5	2
MOFA(Effiduase)	5	2
Naamid Sedi	5	3
Dida	5	2
Bomwire	3	1
Atwima Agogo	3	2
Ejura	4	2
Nyinahini	5	2
Agona-jamasi	3	2
Kwadaso-kokode	5	3
Kwadaso-kokode Agric.sta.	5	2
Adidwan-F2	5	2
Kumso-Mankraso	5	2
Trabuom-F2	3	0
Bosom-Kyekye	4	0
Atwima Foase.no.2	5	1
Worase Manpong	5	0
Trabuom F1	4	3
Sataso F1	4	3
Sataso-Manpong	5	2
Nkrumah Nkwanta-Nyinahini	5	2
Afari-Nyinahini	5	0
Trabuom	4	2
Trabuom-Tellowi F2	5	2
Ejisu juaben-Nyenkrom	5	1
Adidwan F1	5	0
Betiko	5	0
KNUST F1	5	0
KNUST F2	3	1
KNUST F3	4	0
KNUST F4	5	0
KNUST F5	4	1
Total	**178**	**63**

Table 4.5: Insects and birds damage per five maize cobs collected during the minor season in the major maize growing areas of Ashanti Region

	No. of maize cobs damaged per pest	
Comminity	**Insect**	**Bird**
KNUST F1	2	0
Nsima	5	1
KwadasoF1	3	4
Kwadaso F2	2	2
Mankraso	2	2
CRI-Kwadaso	0	0
Seed Compound	2	1
KNUST F2	2	2
Effiduase-Daako	2	1
Afari	3	1
Dida	2	2
Manpong-Sataso	3	0
Adidwan	1	0
Atwima Foase	2	3
Nyinahini	3	0
Atwima Agogo	1	1
KNUST F5	1	1
Ejisu-Donasu	2	0
KNUST F3	3	0
KNUST F4	2	0
Total	**43**	**21**

Generally, insect damage was greater than bird damage in both seasons (Tables 4.4 and 4.5).

4.5 Moisture Content of maize samples

Insects and ear rot pathogen metabolic processes can increase the level of moisture content in maize kernels. Abiotic factors such as the relative humidity of the ecosystem can impact the moisture content of the maize. Tables 4.6 and 4.7 show a summary of the moisture contents of the maize samples analyzed during the major and minor seasons, respectively. For the major season, the moisture contents ranged between 11.2 and 48.2 %. The highest moisture contents was recorded in samples from KNUST F1 (48.2 %), followed by Ejisu-Donasu (38.2 %) and KNUST F4 (32.5 %). The least moisture contents (11.2 %) were recorded for samples from Betinko (Table 4.6). For the minor season, the moisture contents ranged from 8.7 to 18.1 %. The highest moisture contents were recorded in samples from Nsima and Adidwan (18.1%), followed by CRI Kwadaso (17.8 %) and Mankranso (17.4 %). The least moisture content (8.7 %) was recorded for samples from Effiduase-Daako (Table 4.7).

Table 4.6: Moisture content of maize samples collected during the major season in the major maize growing areas of Ashanti Region

Community	% Moisture content
Jacobu MOFA	29.3
Jacobukrom	26.7
Kwaso(Ejisu Juaben)	21.2
Akuakrom	21.2
Deyasi-Bekwai road	34.1
Ejisu Donasu	38.2
Juaben	29.3
Ejisu juaben-Yaw Nkrumah	27.9
Yaw Nkrumah-Ejisu juaben F2	27.4
Senchi(Effiduase)	14.9
Daako(Effiduase)	15.8
Odurokrom	22.9
Apimaso(Effiduase)	18.4
MOFA(Effiduase)	23.4
Naamid Sedi	17.3
Dida	20.0
Bomwire	20.6
Atwima Agogo	17.4
Ejura	21.2
Nyinahini	17.3
Agona-jamasi	17.3
Kwadaso-Kokode	18.5
Kwadaso-Kokode Agric. Sta.	18.3
Adidwan-F2	20.7
Kumso-Mankraso	20.9
Trabuom-F2	18.4
Bosom-Kyekye	15.9
Atwima Foase .no2	15.7
Worase Manpong	13.6
Trabuom F1	27.9
Sataso-F1	18.0
Sataso-Manpog	16.4
Nkrumah Nkwanta-Nyinahini	19.7
Afari-Nyinahini road	17.1
Trabuom	13.3
Trabuom-Tellowi F2	16.2
Ejisu juaben-Nyenkrom	18.2
Adidwan F1	22.9
Betinko	11.2
KNUST F1	48.2
KNUST F2	27.3
KNUST F3	30.6
KNUST F4	32,5
KNUST F5	21.3

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Table 4.7: Moisture content of maize samples collected during the minor season in the major maize growing areas of Ashanti Region

Community	% Moisture content
Kwadaso F1	16.6
KNUST F1	16.6
Seed Compound Nfansi	17.3
Mankranso	17.4
CRI-Kwadaso	17.8
Nsima	18.1
KNUST F2	17.0
Kwadaso F2	16.8
Effiduase-Daako	8.7
Ejisu-Donasu	12.5
Atwima Foase	9.2
Mampong-Sataso	8.8
Dida	8.8
Atwima-Agogo	13.5
Adidwan	18.1
Afari	15.4
Nyinahini	16.0
KNUSTF5	9.1
KNUST F3	13.0
KNUST F4	10.2

CHAPTER FIVE

5.0 DISCUSSION

5.1 Survey: Assessment of farmers' perceptions and management of maize ear rots in the major maize growing areas of Ashanti region of Ghana

5.1.1. The Socio-Demographic Characteristics of Respondents

The results from the survey revealed dominance of female farmers against male farmers (Table 4.1). This may be due to the fact that most of the females are domestic wives, therefore, engaged in the labour intensive work of maize cultivation. The majority of the farmers were in the age range of 41 to 54 years which demonstrates an actively middle-aged farming population; implying maize cultivation is not attractive to the youth (Figure 4.1). A large percentage of the farmers (77 %) had very low level of education (Figure 4.2). Poverty levels are high among farmers in Ghana and this may explain the limited number of farmers with formal education (Wilson *et al*., 2014).

5.1.2 The farming practices of maize farmers in Ashanti Region

Most of the respondents have been cultivating maize for the last twenty years (Figure 4.3) and this is probably due to the fact that they consider maize cultivation a profitable venture due to the high demand for the crop in Ghana. The majority of the farmers obtained their seeds from the Ghana Seed Company, while others used their own saved seeds (Figure 4.4). This might be because some of the farmers cannot purchase seeds from agrochemical shops due to financial constraints, while others have confidence in the viability of their own seed stocks (Bockarie-Kugbe, 1994; Tripp, 1997).

The commonly grown maize variety in the Ashanti Region of Ghana is Obaatanpa. This might be due to high demand for this variety because of its high protein content. The yellow maize is the second most grown maize variety, probably due to its capacity to produce popcorn and serve as feed for livestock (Figure 4.5). Majority of the farmers sow their seeds during the rainy season in Apri1 (ejuradumase.ghanadistricts.gov.gh) which is an ideal time for maize production; but this is also the time for the prevalence of the ear rot pathogen (Figure 4.6). The transportation of the inoculum and subsequent germination of the spores depend on rain. This may explain why the disease is more prevalent during the rainy season.

The majority of the farmers indicated three months as the maturity time for the maize they cultivate (Figure 4.7). According to Alakonya *et al*. (2008), delay harvesting until the rainy seasons may cause maize ear rot infection, as the rain may increase the maize moisture contents, making the crop more susceptible to ear rot infection. This explains the importance of early harvest in maize production.

The majority of the respondents observed symptoms of ear rots by the time the ears mature. (Figure 4.8). Early observation of the disease symptoms could be very essential for proper management and could be vital to reducing maize ear rot prevalence. Farmers may have limited understanding of proper management practices to reduce maize ear rot prevalence and this may explain why they spot the symptoms at the very late stages. The respondents encountered maize ear rot during both the major and the minor seasons (Figure 4.9). This may probably be due to the variations in sowing and harvesting of the crop.

5.1.3 Management of maize ear rots by farmers in Ashanti Region

Majority of the farmers used sun drying as the method of choice for controlling maize ear rot (Figure 4.10). The spores of most fungi are resistant and can withstand intense heat intensely for long periods of time. The spores may not be eradicated by this method but instead build up as inoculum for another season and cause devastation (Sweets and Wright, 2008). Burning is another popular method used by the farmers to control maize ear rot (Figure 4.10). Burning has an adverse effect on the environment; it kills organisms indiscriminately and pollutes the environment and increases greenhouse gases. According to (PAS, 2000), the best option for controlling maize ear rot is the burial of infected residue which reduces the disease inoculum.

The majority of the farmers had no prior knowledge of chemicals used to combat maize diseases. Round up, a weedicide, appears to be the most popular chemical amongst the farmers interviewed (Figure 4.11). None of the farmers interviewed used a fungicide and this may probably explain the prevalence of maize ear rot in the study area. The farmers either cannot afford to purchase chemicals or they are simply not aware about the use of fungicides to combat maize diseases.

5.1.4 Maize cropping system used by farmers in Ashanti Region

Intercropping appears to be the major system of cropping used in Ashanti region of Ghana. The majority of the farmers used cassava as an intercrop with maize (mofa.gov.gh), followed by cocoyam and legumes (Figure 4.12).

5.2 Types of maize ear rot fungi isolated during the major and minor seasons

A total of seven fungi were isolated from the maize samples obtained from the various communities in Ashanti Region of Ghana during the major season.

5.3 Prevalence of maize ear rot in the major maize growing in Ashanti region of Ghana

Maize ear rot infection has led to great damage of the crop, leading to reduced maize yield and, therefore, posing serious concern to global food security (Guest and Brown, 1997).

For the major season, the most prevalent ear rot pathogen was *Aspergillus flavus*. However, not all of the fungi isolated are known to cause maize ear rot. According to Bigirwa *et al*. (2006), *A. flavus*, *Fusarium* sp., *A. niger* and *Penicillium* sp. are examples of fungi known to cause ear rot. Fungi such as *Colletotrichum* sp., *Trichoderma* sp. and *Curvularia* sp. are only associated with ear rot but are not known to cause maize ear rot disease (MacDonald and Chapman, 1997). Though these fungi are not known to cause ear rots, there are contrasting views from other authors relating to their levels of pathogenicity of ear rots (Dupont Pioneer Hi-Bred, 2014). *Curvularia* sp. was the least prevalent during the major season (Table 4.2).

Maize moisture content serves as an indicator of the metabolic activities of maize ear rot pathogens. It increases with insect infestation activities during storage on the maize kernel as well as high relative humidity. The high moisture content of the maize, coupled with the high rate of insect damage, could be responsible for the high prevalence of *A. flavus* infection in maize samples as reported in this study. Poor storage facilities could be a factor responsible for the high moisture content recorded during the major season (Table 4.6). According to Isakeit and Prom, (2003), the high moisture content of the infected maize may contribute immensely to the growth of the pathogen on healthy maize cobs during storage. This probably explains high prevalence of maize ear rot during the major season. The consistent and high isolation of *Aspergillus flavus* should be of concern because of the production of carcinogenic aflatoxin that affects both man and domestic animals (Tuner *et al.* 2003). *Aspergillus flavus* has detrimental effect during storage while the relative humidity and temperature are high (CAST, 2003).

Fusarium sp. was only isolated in the major season. According to Velluti *et al*. (2000), Fusarium infection and subsequent growth is facilitated by high moisture content of more than 18-20%. The low moisture content range (8.7-18.1%) reported in maize samples collected during the minor season (Table 4.7) probably explains the absence of *Fusarium* sp.

Insect and bird damage may also be a factor responsible for ear rot prevalence. According to Munkvold and Desjardins (1997), insects create wounds that facilitate ear rot infection of maize. On average, there was a higher rate of insect and bird damage on maize samples collected during the major season (Table 4.4), compared to those collected during the minor season (Table 4.5). This could also be responsible for the high prevalence of maize ear rot during the major season as compared to the minor season.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

This work was aimed at determining the prevalence of maize ear rots in the major maize growing areas of Ashanti Region of Ghana.

A survey conducted in thirty-nine communities in the major maize growing areas of Ashanti Region showed a clear (70 %) female dominance amongst respondents. About 43% of the respondents were middle-aged and a vast majority (77 %) of the farmers interviewed had education only up to primary level. Majority of the respondents (43 %) had more than two decades of experience in maize cultivation. Most of the farmers (48 %) obtained their seeds from the Ghana Seeds Company and Obaatanpa (59 %) is the variety of choice in the study area. About 66 % of the farmers planted their maize seeds in the month of April and the majority of the respondents (61 %) chose three months as the ideal length of time required for the maturity of the crop. The majority of the respondents (84 %) observed symptoms of maize ear rot at the time of maturity of the crop. Sun drying of debris was the popular method used to control maize ear rot. Majority (68 %) of the farmers interviewed had no prior knowledge of fungicidal applications. Round-up (21 %) is the chemical of choice amongst maize farmers in the region, while none of the respondents used a fungicide.

Seven types of fungal pathogens were identified: *Colletotrichum* sp. *(39.5 %), Aspergillus flavus (40.4 %), Penicillium* sp. *(1.9%), Fusarium* sp. *(4.1 %), Aspergillus niger (2.8 %), Trichoderma (10.3 %), and Curvularia* spp. *(0.94 %)* during the major season.

Five fungal pathogens in four genera were isolated during the minor season. They were: *Colletotrichum* sp. *(65.2 %), Aspergillus flavus (29.4 %), Penicillium* sp. *(1.1 %), Trichoderma* sp. *(3.3 %)* and *A. niger (1.1 %).*The most prevalent ear rot pathogen isolated was *A. flavus* (40 %) followed by *A. niger (3 %) and Penicillium* sp. (3 %).

The types of fungi causing maize ear rot in the major maize growing areas in the Ashanti Region of Ghana are *A. flavus*, *Penicillium* sp., *Fusarium* sp., *A. niger, Trichoderma and Curvularia* spp.

Colletotrichum sp. was the only fungus identified that is associated with maize ear rot in the major maize growing areas in the Ashanti Region of Ghana.

Moisture content, insect damage, bird damage, temperature, relative humidity and poor storage facilities were the main factors identified that influence maize ear rot infection in the study area.

With these findings, it is concluded that majority of the farmers did not perceive the occurrence and impact of maize ear rots.

6.2 Recommendations

The following recommendations are being made based on the findings of this research work:

- Farmers should be educated about the use and application of proper control methods aimed at reducing ear rot inoculum density on maize with minimum impact on the environment.
- Workshops should be conducted aimed at improving farmers' knowledge on the occurrence and impact of maize ear rot.
- Characterization of the maize ear rot pathogens, using specific genetic primers, should be conducted.

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APPENDICES

APPENDIX 1. Questionnaires for: Assessment of Maize Ear Rot In Major Maize Growing Areas of The Ashanti Region of Ghana

Background Characteristics

Study number…………………………………………………

Age…………………………………………………………………………

SEX: (1) Male ☐) Female ☐

1(a) what is your level of education?

………………………………………………………………………………………………

…………………………………………………………………

(b)What is the name of your community or village?

………………………………………………………………………………………………

…………………………………………………………………

(c)How long have been cultivating maize?

………………………………………………………………………………………………

…………………………………………………………………

(d)Which varieties of maize do you currently cultivate?

	VARIETIES	ACREAGE	REASONS FOR

(e)Where is the source of your seeds?

…………………………………………………………………………………………………

(f)What other sources of seeds do you know?

…………………………………………………………………………………………………

(g)Which month do you start planting?

…………………………………………………………………………………………………

2. (a)How long does it take to harvest after maturity?

(b)When do you see ear rot?

(c)Which season is it common?

……………………………………………………………………………………

(d)Have you ever had any bad harvest?

……………………………………………………………………………………

(e)If yes, what is the cause of the bad harvest?

……………………………………………………………………………………

(f)Do you use any chemical?

…………………………………………………………………………………

(g)Which commonest type of chemical is known to you?

………………………………………………………………………………………………

(h)Which pest and diseases do you encounter from your maize? …………………………

Pest		Rank	Diseases		Rank
NAME	DESCRIPTION		NAME	DESCRIPTION	

(i)Can you show sample of the pest or diseases?

………………………………………………………………………………………………

(j)What are the control measures?

………………………………………………………………………………………………

3. (a)Which type of farming system do you practice?

………………………………………………………………………………………………

(b)What intercrops do you use?

………………………………………………………………………………………………

(c)Do you receive any subsidy?

…………………………………………………………………………………………………

(d)If yes, from which organization?

…………………………………………………………………………………………………

(e)Do you receive extension officers from MOFA?

…………………………………………………………………………………………………