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OCCURRENCE AND PATHOGENICITY OF CROWN ROT DISEASE ORGANISMS IN MAJOR BANANA PRODUCING AREAS IN ASHANTI REGION

BY

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A THESIS SUBMITTED TO THE SCHOOL OF RESEARCH AND GRADUATE STUDIES, KWAME NKRUMAH UNIVERSITY OF SCIENCE AND TECHNOLOGY, IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF MASTER OF SCIENCE (MSc. POSTHARVEST PHYSIOLOGY) DEGREE

BY

EMMANUEL ADJEI ODAME

JANUARY, 2010

DECLARATION

I hereby declare that, except for specific references which have been duly acknowledged, this project is the result of my own research and it has not been submitted either in part or whole for any other degree elsewhere.

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DEDICATION

This work is dedicated to:

Mrs. Mary Anima (Sweet Mother)

and

My siblings:

Fausty, Sammy, Micky, Lizzy and Joe.

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LIST OF ABBREVIATIONS

CRI	Crops Research Institute
FAO	Food and Agriculture Organization
GEPC	Ghana Export Promotion Council
IITA	International Institute of Tropical Agriculture
KMA	Kumasi Metropolitan Assembly
KNUST	Kwame Nkrumah University of Science and Technology
MoFA	Ministry of Food and Agriculture
PDA	Potato Dextrose Agar
VREL	Volta River Estate Limited

ABSTRACT

A study was conducted to investigate the occurrence of crown rot disease pathogens in major banana producing areas in the Ashanti Region of Ghana from April to September, 2008. Field survey was conducted in eight districts including Asante Akim South, Asante Akim North Municipality, Ejisu-Juabeng Municipality, Sekyere East, Sekyere South, Mampong Municipality, Kwabre East and Offinso South. Interviews together with semi-structured questionnaires were used in data collection from farmers who were randomly selected from each location. Fifty-six farmers were interviewed from the eight districts. Laboratory work was also conducted at the Plant Pathology Section of the Crops Research Institute (CRI), Fumesua, Kumasi. Crown rot diseased banana samples collected from the eight districts were used for the laboratory study. The survey revealed that 82.1% of farmers practiced mixed cropping farming system with food crops such as cassava, plantain, cocoyam, maize and vegetables including garden eggs, tomato, pepper and okra. Banana suckers from farmers ratoon fields (64.2%) were used in farm establishment. Cultural activities such as weed control (98.2%), mulching (25%), pruning (62.5%) and disease and pests management (23.2%) were practiced. Manual weeding of farm was done three times in a year (53%), dry banana leaves (72.7%) were used in mulching and pruning of dry and diseased banana leaves (100%) were also done. De-budding was practiced in Sekyere South and Offinso South districts. Poor preharvest practices such as mulching with diseased banana leaves, no mulching, pruning at the wrong time and the retention of flower bract and male inflorescence were found to influence the occurrence of crown rot disease in the districts. Machete was the main tool used in harvesting mature bunches. After harvest, whole banana bunches (82.7%) were sent to the market. *Botryodiplodia*

theobromae was frequently isolated from Asante Akim South, Asante Akim North Municipality and Offinso South Districts. *Fusarium semitectum* was isolated from Mampong Municipality and Kwabre East Districts. *Colletotrichum gloeosporioides* was isolated from Ejisu-Juabeng Municipality, Sekyere East and Sekyere South Districts. *B. theobromae, F. semitectum* and *C. gloeosporioides* were the primary pathogens identified to be associated with crown rot disease. These three fungi were able to cause the crown rot disease when inoculated (singly) into healthy banana crowns and in different combinations. *C. gloeosporioides* alone, *B. theobromae + C. gloeosporioides* and *B. theobromae + C. gloeosporioides + F. semitectum* caused a disease severity score of 4 (on a scale of 0-4) in seven days when inoculated into healthy banana crowns. *B. theobromae* alone, *C. gloeosporioides + F. semitectum* and *B. theobromae + F. semitectum* caused a disease severity score of 4 in eight days while *F. semitectum* caused a disease severity score of 3 (75% infection) in eight days when inoculated into healthy banana crowns. Combination of *B. theobromae* and C. *gloeosporioides* recorded the highest rot length of 3.7cm with a disease severity score of 4 eight days after inoculation while *B. theobromae* inoculated singly had a mean rot length of 2.9cm. However, *Aspergillus flavus, Aspergillus niger* and *Aspergillus terreus* were found to be secondary invaders (saprophytes) taking advantage of the disease condition created.

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1.0 INTRODUCTION

Banana is one of the most popular fruits in terms of per capita consumption and is among the least expensive fruits available on the world market today. In the United States of America, banana is ranked among the most consumed fruits and is also considered as a favourite fruit in the United Kingdom (Dadzie, 1999). It forms an important component in the diet of tropical third world countries because of its nutritional composition and wholesomeness (Thangavelu *et al*., 2007). The flavour, texture, convenience, ease of eating and the nutritional value of dessert banana has contributed to its popularity (Baldry *et al*., 1981). A minor proportion of the world production is processed into other forms (Nakasone and Paull, 1998).

Banana is consumed as a staple food, fresh fruit or for processing. It also serves as a boost to farm income for millions of people in the tropical region. It is an important source of high-calorie energy and contributes about a quarter of the energy requirement of almost 70 million people in the West and Central African sub-region (Swennen, 1990; IITA, 1992). In some cases, it is used in special diets where ease of digestibility, high mineral and vitamin contents as well as low fat and no cholesterol are required (Wainwright, 1992).

In Ghana, banana constitutes about 13% of the total horticultural exports and is among the cheapest staple foods produced (FAO, 2001). Total domestic banana production was estimated to be about 100,000 metric tonnes with a per capita consumption of about 4.1 kg/annum (FAO, 2004). Although banana has a lesser importance as a basic food item, it has become an important export commodity. The FAO, however, reported in 2001 that the

banana export industry in Ghana was fragile and depended on one plantation - the Volta River Estate Limited (VREL), whereas according to Dadzie (1998) in Latin America and the West Indies, banana exports contribute immensely to the growth of their economy. Ghana Export Promotion Council (2006) reported that Ghana in 2006 earned about US $10.3 million in foreign exchange from 44,098 metric tonnes of banana exported.

There are numerous constraints pertaining to the expansion of the banana export industry worldwide. Production has been seriously threatened by decreasing soil fertility and pests and diseases problems. The greatest obstacle by far is the prevalence of the Black Sigatoka Disease caused by *Mycosphaerella fijiensis* Morelet. The disease destroys large areas of the leaf tissue resulting in reduced yield and premature ripening of fruit (Gowen, 1995). Yield losses as high as 50% have been reported in some cases (Mourichon *et al*., 1997). In commercial export plantations, Black Sigatoka is controlled by frequent applications of systemic fungicides, removal of affected leaves, good drainage, and proper spacing. Chemical treatments, though effective, pose health hazards to workers and threaten fragile ecosystems in producing countries (Stover and Simmonds, 1987). The development of resistance by *M. fijiensis* and *M. musicola* strains to some fungicides raises concern and make the disease management more difficult (Mourichon *et al*., 1997).

Several postharvest diseases also affect the industry worldwide. Crown rot and anthracnose diseases had been reported as being the most prominent (Gowen, 1995). Crown rot disease stands out as the most devastating disease affecting the industry worldwide (Snowdon, 1990). During the rainy season, losses of more than 10% had been recorded for Windward Island bananas arriving in the UK (Krauss and Johanson, 2000).

In the Philippines alone, losses as high as 86%, had been recorded in situations where banana fruits did not undergo chemical treatment (Alvindia *et al*., 2000). In Ghana, significant losses due to crown rot are observed in the marketing centres where loss figures are unavailable.

In recent years, a growing number of countries are demanding for chemical-free fresh produce. Exploring new methods to reduce dependency on use of agrochemicals is a worldwide trend. There is the need to develop alternate postharvest treatments that are safe and acceptable to consumers (Ranasinghe *et al*., 2002). However, the incidence of crown rot disease, the frequency of occurrence of different pathogens and their importance as primary pathogens of decay may change with reference to the country of origin. Therefore, to develop an effective disease control programme for the banana sector, it is important to know the fungal pathogens responsible for the disease within a location and the practices that enhance their development.

The objectives of this study, therefore, were to:

identify banana production and postharvest practices that might contribute to crown rot disease occurrence in the major banana producing areas in the Ashanti Region identify the primary pathogens associated with crown rot disease of banana in the major banana producing areas; and determine the pathogenicity of identified crown rot organisms.

2.0 LITERATURE REVIEW

2.1 BANANA

2.1.1 Origin and Distribution

Banana an important crop in the humid tropical lowlands with year-round fruit production belongs to the family *Musaceae* and the genus Musa. Majority of cultivated bananas are derived from the species *Musa acuminata* and *Musa balbisiana*. Edible banana (*Musa paradisiaca* L.) has its centre of origin stretching from India to Papua New Guinea including Malaysia and Indonesia (De Langhe, 1995). It is now cultivated throughout the humid Tropics and Sub-tropics and constitute the 4th largest fruit crop of the world (Baldry *et al*., 1981). Most of the commercial varieties grown are triploids belonging to the AAA group. The three major groups under cultivation all over the world are AAA, AAB and ABB (Marin *et al*., 1998).

2.1.2 Description of the Banana Plant

The banana plant is a tall perennial plant with an underground stem (corm). The roots are adventitious and spread in all directions forming a dense mat (Samson, 1980). Aerial shoots (suckers) are non woody pseudostems composed of tightly packed leaf sheaths rolled around each other in a circular shape. They arise from lateral buds on the rhizome and can grow 2-8m tall. The leaf blade emerges from the middle of the stem and unfurls slowly (Sastry, 1988).

Being monocarpic, the shoot flowers only once. As the apex becomes reproductive, no further leaves are initiated. The corm's life is perpetuated by suckers that are freely formed. The flowering stalk emerges in the leaf crown, hangs down and bear flower clusters in a spiral form. Each cluster bears between 12 and 20 flowers in two rows covered

by bract (red, purple or violet in colour). The bracts rises and drops as the flowers develop. The fruit develops parthenocarpically from the ovaries of the female flowers. The fruit cluster is also known as a "hand" and a single fruit a "finger" (Sastry, 1988).

The plant takes about 10-15 months to produce a flower stalk. High temperatures and bright sunlight may result in scorching of leaves and fruit. In most areas, for best appearance and maximum yield from banana plantations, wind breaks are required as they are very susceptible to destruction from strong winds.

2.1.3 Importance of Banana in Sub-Saharan Africa

Banana is one of the world's most important crops and yet one of the least researched of the major food sources (Schoofs *et al*., 1999). Total world production is estimated at 99 million tonnes in 2001, one third of which is produced in Sub-Saharan Africa. The bulk of which comes from relatively small plots and backyard gardens where statistics are lacking.

In Africa, the bulk of production is consumed or locally traded, playing a crucial role in providing food security. The crop is particularly important in the humid forest and midaltitude regions where it provides more than 25% of the food energy requirements for over 70 million people in Africa (Picq *et al*., 1998). Since bananas produce fruit all year round, it plays an important role in bridging the "hunger-gap" between crop harvests. As a staple food crop, it contributes significantly to food security to millions of people and provides income and employment to rural populace. In West African humid lowlands however, plantains (AAB) dominate banana production systems, and this provides an

important source of rural income, especially for resource-limited farmers (Frison *et al*., 1998). Typical example is seen in Ghana where plantain production far exceed that of banana and forms about 3% of the total food consumed and also serves as an important source of rural income (Banful, 1998).

Bananas are considered as a major source of staple food with an average per capita consumption exceeding 100 kg/year in certain parts of Africa. In East Africa, highland AAA cooking and beer bananas predominate, and serve as a staple food crop. In Uganda, Burundi and Rwanda, annual per capita consumption has been estimated to be between 220-440 kg, the highest in the world (Karamura, 1992). In Gabon and Cameroon, per capita consumption is estimated between 100 and 200kg; accounting for between 12-27% of daily calorie intake of their populations (Arias *et al*., 2003). In
Ghana, banana is usually consumed as dessert throughout the country (Banful, 1998).

Although bananas come fourth after rice, wheat, and maize with regard to gross value on the global scale, the crop actually comes second after cassava in Sub-Saharan Africa (Frison *et al*., 1998). As an export commodity, banana is a key contributor to the economies of many low income food deficit countries like Cameroon and Côte d'Ivoire (Arias *et al*., 2003).

A wide range of genetic diversity of bananas is found in Africa, with different types being specifically adapted to different sub-regions. The crop is environmentally friendly and can be used to combating soil erosion on hilly slopes, and readily lends itself to intercropping and mixed farming (Frison *et al*., 1998).

2.2 FACTOR AFFECTING THE BANANA INDUSTRY

2.2.1 Agronomic Factors

Banana production systems in Africa are characteristically complex; even on one farm ranging from single cultivar to multiple cultivars, mixed cropping and mixed farming systems. In parts of Africa there are expensive commercial farms and semi-commercial farms but in most parts, the crop is grown for subsistence purposes as a backyard garden crop or as smallholdings of few hectares, whereby only the surplus is sold (Speijer *et al*., 1999). In West, Central and Eastern Africa, banana may be produced under systems of shifting cultivation or in permanent farming systems where they are often grown in association with tree crops, such as coffee and cocoa. They may also be produced in intensively managed home gardens where they benefit from the regular application of manure and organic matter from household refuse.

2.2.2 Pests and Diseases

Pest and disease pressures have also increased considerably in recent years, leading to a situation where a well-managed banana garden begins to deteriorate after only 4 years. Black Sigatoka and Fusarium wilt are the most devastating diseases affecting production. They attack both the traditional and the widely grown banana and plantain cultivars of West, Central and Eastern Africa causing considerable losses in yield (Stover and Simmonds 1987). Similarly most farmers do not apply pesticides to control the numerous pests and diseases that have emerged on the crop, nor do they maintain crop hygiene to bring down pests and disease incidence. The traditional method of using planting materials

from existing stands has helped in the spread of pests and diseases. The complexity in production systems is also matched by a multitude of pest problems (Frison *et al*., 1998).

2.2.3 Soil Fertility

Soil fertility in banana production systems is a top-rated constraint in the region. In Uganda, declining soil fertility coupled with poor agronomic practices and invasion of new pests and diseases have severely affected banana production over the past 15 years (Karamura, 1993). Although intensively managed home garden systems worked well in the past, they are now unable to meet the demands of a rapidly growing population. Rising population pressure on the land has led to shortened fallow periods and consequently declining soil fertility (Karamura, 1993; Kena 1996). Banana production systems are characterized by low-input application. In general most farmers do not apply inorganic fertilizers or technical know-how. Consequently soil fertility is progressively on decline in these systems (Frison *et al*., 1998).

2.2.4 Human Factor

Similarly, farm management is also extremely variable to include household, hired and communal labour; all three sometimes occurring on the same farm. Equally variable are the purposes for which the crops are grown (Frison *et al*., 1998).

2.3 THE BANANA INDUSTRY IN GHANA

In Ghana, the non-traditional export sector over the years had been identified as an area that could supplement Ghana's foreign exchange earnings. Apart from being a potential exchange earner, very little has been done in sustaining it. The banana industry is made

up of smallholders who usually grow banana in backyard gardens, in mixed field cropping, in association with trees crops and sometimes in intensive monocropping systems. According to Banful (1998), intercropping dominated most cropping systems in Ghana where principal crops such as cocoa, coffee, citrus and oil palm are intercropped with seasonal food crops such as maize, cocoyam, cassava and yam.

The World Bank estimate on Ghana shows that the country needs close to 60,000 tonnes of banana a year to make her industry sustainable. Currently, Ghana is producing about 5,000 tonnes a year, while neighbouring Cameroun and Cote d'Ivoire are producing the same figure every fortnight. These figures according to the World Bank estimates show that the country has a lot of potential in developing the industry to create more employment for the rural poor by making up for the shortfall of 55,000 tonnes needed to make an impact on the international market (Anonymous, 2001).

Golden Exotics Limited and Volta River Estates Limited (VREL) all situated in the Eastern Region of the country are the two major exporting companies in Ghana. Golden Exotics Limited, which is owned by a subsidiary of Compagnie Fruitiere Limited employs over 2000 workers and has large conventional plantations. Volta River Estates Limited on the other hand, is owned by Agrofair - a Fairtrade organisation from the Netherlands and other shareholders in Ghana, is the oldest banana company in the country. VREL employs over 750 workers and their operation is about 90% organic (Adjei-Mensah, 2009). VREL earns between US$1.5million to US$1.8 million a year.

Over the years, the banana industry has not received the needed support from government to increase its impact on the international market. With proper support (e.g. financial), the banana industry can increase production and generate more jobs in the areas of curtains, twine and other packaging material production much needed by the banana industry. Income levels can be increased from the present levels of US$1.8 million to about US$3.6 million if production for export is doubled (Anonymous, 2001).

2.3.1 Agro-Ecological Zones in Ashanti Region

The Ashanti Region is located in the middle belt of Ghana. It lies between longitudes 0°15′ - 2°25′ West and latitude 5°50′ - 7°40′ North. It is situated between 150 and 300 metres above sea level (KMA, 2007). The region lies within the wet, semi-equatorial forest zone with two distinct types of vegetative cover; the moist semi-deciduous forest found south of the mountain range and the forest-savannah transition zone found in the north-eastern part of the region (Biederlack and Rivers, 2009).

The vegetation consists of fallow lands, secondary forest, thickets, forb growth and swamps (Adu, 1992). Due to human activities and bushfires, the forest vegetation in the north-eastern part of the region has been reduced to guinea savanna. The soil type is the Forest and Savanna Ochrosols. Ground water lateritic intergrade is also found along the Afram River. The region is naturally drained by several rivers and streams. The average daily temperature of the region is found to be around 27°C in the forest zone and 29°C in the northern fringes of the forest zone (KMA, 2007).

The average annual rainfall ranges between 1300 to 1500mm (Biederlack and Rivers, 2009). The region has a bi-modal rainfall pattern consisting of the major and minor rainy seasons. The major rainy season starts in March with a peak in May-June and a slight dip in July. The minor season starts in August tapering off in November. The dry season which begins in December and ends in February is characterized by very dry, hot and dusty weather (MoFA, 2006). Mixed cropping with crops grown in mixed stands or pure stands are practiced. Cocoyam, plantain, banana, yams, maize, rice, cassava and vegetables such as pepper, garden eggs, okra, onions and tomato are the most common crops cultivated (Adu, 1992).

2.4 POSTHARVEST DISEASES OF BANANA

Fruits (fresh from farm or ripened) often meet low demand resulting in overstocking of markets and storage facilities. Fresh produce serve as a suitable substrate for the development of pathogens that causes rot because of its rich source of moisture and nutrients. Pathogen attack during storage remains one of the major causes of deterioration in fresh produce. According to Barkai-Golan (2001), the economic losses incurred through storage diseases far exceed that of field diseases because of the huge investments in the overall treatments and processes the product undergoes from harvest until it reaches the customer. In places where advanced technologies such as computerized sorting and grading, improved packing materials and methods as well as modified atmosphere storage are not used, postharvest losses due to diseases remain substantial.

Development of diseases during storage depends primarily on the existence of appropriate pathogen and a suitable host. Infection of host tissue occurs when appropriate conditions

exist for spore germination, penetration and subsequent disease development. According to Barkai-Golan (2001) harvested fruits become prone to attacks, as they ripen, by various pathogens. Produce gradually losses their resistance during storage as ripening makes them more susceptible to injury and attack by pathogens that require injuries or damaged tissue for successful penetration. Pathogens responsible for storage decay often originate in the field. Fungal spores are typical components of the airborne microorganism population on the fruit during their growth and may be transferred into storage together with the harvested fruits.

A critical examination of the fungal spore population on the surface of stems, leaves, flower parts, fruits and other plant parts after harvest may reveal the presence of many important airborne pathogenic fungi such as species of *Alternaria, Aspergillus, Rhizopus,* and *Fusarium* among others. Furthermore, most postharvest pathogens thrive well on crop debris in the field, and under suitable conditions, develop and produce abundant new spores. These form a potential source of infection as they are easily carried by air current, wind, rain and by insects onto flower parts and young fruits at different stages of development. Soil, irrigation water and plant debris are primary sources of infection of various crops. Host infection can occur at pre-harvest, during harvest or during any of the postharvest handling stages. Harvesting instruments, containers, the handlers and the storage room atmosphere are all sources of fungal spores. Despite the wide diversity of microorganisms found on the fruits surface, only a few species naturally attack banana (Barkai-Golan, 2001).

2.4.1 Factors Affecting Disease and their Development

2.4.1.1 Pre-harvest factors

The quality of planting material used in establishing a plantation is very important often in determining the health of plants and the subsequent yield. Unhealthy planting materials may result in unhealthy young plants that can easily be attacked by several of the diseases of banana in the field. Environmental conditions during crop growth also impact on the yield and quality of the produce (Sharpies, 1984; Eden *et al*., 1996).

A number of diseases of banana including wilt have pathogens that are soil borne. Continuous cultivation of banana on the same plot of land for years may result in an increase in the inoculm level of soil borne pathogens. Most pathogens may survive in soil as well as on plant debris in the field and may be dispersed directly to potential hosts through wind or rain. Also proper soil management can help reduce further these harmful organisms (Katan, 1987).

Plant debris including old stems and pruned leaves when not destroyed can harbor pathogens for a long time. These can be the source of inoculum for future infection. Cultural practices such as pruning and subsequence destruction of crop debris can markedly affect the survival of such pathogens (Palti, 1981). Legard *et al*. (1997) stressed that inoculum levels of pathogens can be reduced further through proper field sanitation which hinders disease development. However, the application of preharvest fungicides sprays in the field can enhance the development of new strains of fungi resistant to fungicide (Eckert and Ogawa, 1988).

2.4.1.2 Harvesting and handling operations

According to Kader *et al*. (1985), harvesting by hand has been the most predominant method for fruits destined for the fresh produce market. Selecting produce with optimal maturity help reduce damage to a minimum. Substantial damage to commodity also serves as suitable areas of infection for wound pathogens. Unfavourable weather conditions, such as rain prior to harvesting, are likely to increase the risk of infection, even in matured fruits ready to be harvested. The time of harvesting in the day may also affect the quality of the produce. The risk of damage and subsequent infection accompany fresh produce from harvesting to handling in the field through transportation to the packinghouse, storage room and to its final destination (Barkai-Golan, 2001).

2.4.1.3 Inoculum level

The amount of inoculum available is very important for a successful infection to occur. Infection studies with fungal spore suspensions on different hosts showed that increasing the spore concentrations frequently leads to higher rates of infection and lesion formation. Eden *et al*. (1996) demonstrated the practical importance of reducing the inoculum level on the crop in order to minimize infection. Postharvest pathogen infection is dependent on the availability of wounds for a successful penetration into the host tissue. Disease development is related to the pathogen spore load on the fruit surface and the availability of wounds for penetration. Reducing the inoculum level, preharvest and postharvest injury forms the basis for the control of postharvest infections initiated by wound pathogens. According to Edney (1983), the incidence of rotting is influenced by the number of viable spores at potential infection sites when the fruit is at the stage of ripening (which is suitable for infection to develop). Coertze and Holz (1999), however, also found that infection was

not always governed by conidial density on the fruit surfaces, but rather by the level of host resistance.

2.4.1.4 Temperature of storage

Temperature constitutes basic limiting factor in the development of a disease. The optimal temperature for growth of most storage fungi ranges between 20°C and 25°C, though some species may require higher or lower temperatures. However, the optimum for growth is not necessarily identical to that for germination. According to Sommer (1985), the minimal developmental temperature for some fungi may be below 0°C. On the other hand, pathogens such as *Colletotrichum spp*. or *Aspergillus niger* mycelia are susceptible to low temperatures. *Colletotrichum* species which are pathogens of tropical and subtropical fruits however, can easily develop in these fruits during storage. Environmental temperature affects both the host and the pathogen simultaneously. In fact, a significant proportion of the decay that occurs in the markets, particularly that of tropical fruits, results from overexposure to damaging temperatures (Barkai-Golan,
2001).

2.4.1.5 Relative humidity of storage

High relative humidity (RH) required for produce protection against dehydration and weight loss may also stimulate pathogen development during storage. Danger of decay is enhanced by the condensation of mist over the fresh fruit surface. Many fruits become more susceptible to pathogens when their tissues are in a turgid state under high relative humidity. Increased decay rate in many crops are mainly due to the moisture held within

the wounds, lenticels or stomata which favours fungal spore germination prior to penetration into the host tissues (Barkai-Golan, 2001).

2.4.1.6 The storeroom atmosphere

The atmosphere in which fresh fruits are stored directly affects the development of fungal mycelium in the plant tissue as well as spore germination on the fruit surfaces. Yet, like other environmental conditions, the storage room atmosphere simultaneously affects the host, the pathogen and their interrelations. In view of the fact that the atmospheric gas composition can significantly affects the ripening and senescence processes of the host and because the physiological state of the host also affect its susceptibility to disease, the composition of atmospheric gases indirectly affects decay development in the host tissue (Barkai-Golan, 1990).

2.4.1.7 Conditions pertaining to the host tissues

Acidity levels in fruits play an important role in its deterioration. Fruits characterized by low pH (pH < 5), enhances the postharvest development of various fungi. Most of the decays found in fruits are mainly due to fungi rather than bacteria since the latter require high pH to operate. Certain compounds found in the host tissue may influence the susceptibility of the host to infection through stimulating pathogen growth. Ascorbic acid and a number of terpene compounds found in some fruits stimulate spore germination and mycelia growth (Arimoto *et al.*, 1995). Thus, the presence of fruit juice with the appropriate acidity level affects both the germination rate, rate of fungal development and the incubation period of the disease (Barkai-Golan, 2001).

2.4.1.8 Fruit ripening stage

Susceptibility of harvested fruits to decay pathogens depends principally on the ripening stage at the time of picking since it increases with ripening. Most fruits become prone to injuries as they ripen and, therefore, become more vulnerable to pathogen (BarkaiGolan, 2001). Nevertheless, the susceptibility of fruits to pathogen invasion increases regardless of its susceptibility to injury. Thus tissue characteristics such as acidity level, turgor or nutrient availability changes as ripening progresses and may separately or in combination enhance the fruit susceptibility to disease (Paull *et al*.,1999). Johnson *et al*. (1998) also reported that in young banana fruits, tannins which inhibit pathogen growth diminish as the tissues ripen. Polyphenols and tannins highly concentrated in younger fruits are both germination and growth inhibitors of decay pathogens and as suppressors of enzymatic activity. Compounds such as monoene and diene found in young avocado skin and resorcinols found in the skin of mango in their early developmental stages are also reported to inhibit decay pathogens (Prusky and Keen, 1993). A direct relationship was also established between the sugar contents and fruit susceptibility to infection regarding nutrient availability changes during ripening of the fruit (Fourie and Holz, 1998).

2.4.1.9 Effects of ethylene

A strong relationship between ripening stage of a fruit and its sensitivity to decay may explain why conditions that stimulate ripening usually enhance decay. A classic example is the exposure of produce to ethylene for de-greening when fruit maturity is reached but the desired colour is not yet developed by enhancing chlorophyll breakdown and sensitivity of the fruit to decay (Brown and Lee, 1993). Flaishman and Kolattukudy (1994)

reported that ethylene treatment at concentrations much lower than those produced during ripening of climacteric fruits was capable of inducing both conidia germination and appressoria formation in *Colletotrichum musae* and *C. gloeosporioides* and that endogenic ethylene produced in climacteric fruits during ripening serve as a signal for the termination of the appressoria latency on the fruit.

2.4.2 Mode of Infection of Host Tissue by Pathogen

2.4.2.1 Latent or quiescent infection

Latent infection of plants by pathogens has been recognized for many years and is often considered one of the highest levels of parasitism, since the host and the parasite coexist with minimal damage to the host (Sinclair, 1991). Agrios (1988) defined latent infection as the state in which a host is infected with a pathogen but does not show symptoms. Sinclair (1991) also defined latent infection as a type of tolerance or resistance to certain pathogens, where the parasite finds the internal environment unsuitable for growth and multiplication. Fungi that penetrate into host tissue in the field can also cause latent or quiescent infection. These pathogens attack the fruit while it is still on the parent plant. However, their growth is arrested between host infection and disease development until the physiological and biochemical changes occurring within the host tissues becomes favourable for growth to continue. Anthracnose, a quiescent infection, caused either by *Colletotrichum musae* in banana fruits or by *C. gloeosporioides* in many tropical and subtropical fruits (Dickman and Alvarez, 1983; Spalding and Reeder, 1986). Fungal conidia are abundant on fruit surface during their development on the tree. Under suitable conditions, the spore may even develop fine infecting hyphae that penetrate under the cuticle or the external layers of the epidermis (Muirhead, 1981; Prusky *et al.*,

1990).

2.4.2.2 Infection through natural inlets

Some pathogens which normally cannot break through healthy host tissue directly can enter through natural openings such as stomata and lenticels. Hong *et al*. (1998), working on brown rot fungus (*Monilinia fructicola*) on stone fruits found that, penetration of the unwounded fruit can take place through the stomata or directly through the peel if inoculum levels are high on the fruit surface. In young papaya fruits, spores of *Colletotrichum gloeosporioides* entered the host through the stomata while the fruit is still on the field. Penetration of avocado fruits by *Dothiorella gregaria* is through the lenticels and remains dormant until the harvested fruit has aged. In mango and persimmon fruits, *Alternaria alternata* also enters through the lenticels (Prusky *et al*., 1981; Prusky *et al*., 1983). *Aspergillus niger*, *Fusarium* spp. and *Botrytis cinerea*, may be responsible for core rot of apples that results from infection through the sinus between the calyx and the core cavity (Combrink *et al*., 1985; Spotts *et al*., 1988).

2.4.2.3 Infection through wounds

In contrast to pathogens that attack fruits in the field, most of storage pathogens are incapable of penetrating directly through the cuticle or epidermis of the host, but may require a wound or an injury to facilitate their penetration. The wound may be growth cracks present on harvested fruits, mechanical injuries and careless separation of fruits from the parent plant might result in an injury rendering the fruit liable to pathogen attacked. According to Fuchs *et al*. (1984), the extent of injury whether a scratch, incision, blow or other mechanical injury inflicted on the fruit during handling processes may

present adequate penetration points for storage pathogens. Penetration through wounds is characteristic of *Penicillium digitatum, P. Italicum, Rhizopus stolonifer, Alternaria alternata, Geotrichum candidum, Aspergillus, Cladosporium* and *Trichotecium* species.

2.4.2.4 Infection following physiological damage

Physiological damage caused by low temperatures, heat, oxygen shortage or any other environmental stress increases the fruit sensitivity and exposes it to storage fungi. The physiological damage can be externally expressed through tissue browning and splitting. Yet extreme environmental conditions might enhance sensitivity to an attack without any visible external signs of damage (Lavy-Meir *et al*., 1989; Barkai-Golan and Kopeliovitch, 1989). According to Snowdon (1992), melons exposed to excessively low temperatures are sensitive to various *Penicillium* and *Cladosporium* species. *Alternaria alternata* and *Stemphylium hotryosum* tend to attack apple fruits following the development of sun scald lesions (Snowdon, 1990). *Cladosporium herbarum* may also be associated with scald and other physiological disorders in some cultivars of apples (Dennis, 1983).

2.4.2.5 Infection following a primary pathogen

It is natural to find several pathogens entering a host following a primary pathogens successful breakthrough. Nature deploys a sequence of pathogens. According to Snowdon (1990), *Penicillium expansum* can enter apple fruits following infection by the fungi *Mucor, Gloeosporium* and *Phytophthora*. The penetration of *Fusarium* species into melon occurs following infection by primary pathogens. Nishijima *et al*. (1990), in their work,

revealed that *Rhizopus stolonifer* was consistently capable of infecting the fruit through existing lesions caused by *Colletotrichum* and *Phomopsis* species.

2.4.2.6 Infection due to tissue senescence

Tissue senescence during prolonged storage reduces the tissue resistance to disease infection. Generally, the rate of decay during storage increases with the duration of storage as tissue senescence progresses. Increasing tissue sensitivity to diseases during storage also contributes to contact-infection of a healthy product by an infected one covered with spore-bearing mycelium. Thus, the sensitivity of stored produce to pathogen attack increases with time. A typical example is seen in melon's sensitivity to *Penicillium spp.* and *Trichothecium roseum* (Barkai-Golan, 2001).

2.4.2.7 Infection through contact

Healthy fruits are liable to attack by pathogens even in storage through contact with infected fruits. Contact-infection is a significant factor in the spread of rot diseases during storage. The development of rots in stored fruits covered with layers of sporebearing mycelium causes a "chain" contact-infection and can jeopardize an entire stockpile of fruits. Similarly, an infected fruit constitutes a focus from which the decay can spread within the container when it is transferred from one condition to the other. In fact, contact-infection by *Botrytis* or *Rhizopus* is typical of many fruits, and may account for the major losses caused by these pathogens during long-term storage. In citrus fruits, contact-infection by *Penicillium digitatum* and *P. italicum is* very common and can under certain conditions, debar an entire shipment (Barkai-Golan, 2001).

2.5 CROWN ROT DISEASE OF BANANA

Several diseases reduce the quality and postharvest life of the banana fruit. Crown rot is one of the most important postharvest diseases of banana. It is characteristically a disease complex caused by several fungi, sometimes in association with other microorganisms including bacteria species (Snowdon, 1990). Two or more of these fungi may attack the crown simultaneously or successively and cause tissue rotting. Different organisms may pre-dominate a particular locality depending on time of year and other factors.

The most common pathogens frequently isolated from crown rot disease complex included *Colletotrichium musae, Fusarium roseum, Fusarium semitectium, Fusarium proliferatum* and *Botryodiplodia theobromae* (Finlay and Brown 1993). *C. musae,* though easily isolated from fruit rots is reported to be highly pathogenic and is responsible for banana anthracnose and crown rot diseases (Muirhead and Deverall, 1981; Coates and Johnson, 1992). Various *Fusarium* spp. are regularly isolated from crown rot disease complexes (De Lapeyre and Mourichon, 1997). Other species such as *Cephalosporium spp*., *Verticillium theobromae, Ceratocystis paradoxa* and *Phomopsis spp*. have also been found in crown rot disease complexes (Snowdon, 1990). In addition, other dozen of pathogenic fungi have also been found in crown rot affected tissues (Ploetz *et al*., 1994).

Principal crown rot pathogens including *C. musae, Fusarium pallidoraseum, V. theobromae, B. theobromae, Acremonium spp., Cephalosporium spp*. and *C. paradoxa* are known to cause significant losses in international trade. In Central America and the West Indies for instance, *C. musae, F. pallidoraseum, Fusarium moniliforme, Fusarium*

moniliforme var. subglutinans, *V. theobromae* and *B. theobromae* were found to be associated with the disease (Wallbridge, 1981).

In South America, *C. paradoxa* and *Fusarium spp.* were among the most common pathogens isolated. Severity of the disease was reported during the hot, dry weather (Marin *et al*, 1996) whereas in the Windward Islands, severity of the disease was seen when rainfall was highest.

In Asia, *C. musae*, *Fusarium* spp. including *F. moniliforme* and *B. theobromae* were frequently isolated from rotting crowns. *Curvularia* spp. and *Gliomastrix musicola* have also been found in Malaysia (Sepiah and Nik Mohd, 1987). Thangavelu *et al*. (2007) reported that in India, crown rot infected banana samples collected from different regions revealed that *Lasiodiplodia theobromae* was the primary pathogen whereas *C. musae* and *Fusarium spp*. were found to be secondary rot organisms.

However, in Australia, *F. pallidoraseum* and *V. theobromae* were more common in the dry period with *C. musae* being more prominent in the wet periods. *Nigrospora sphaerica*, although rare, is also known to incite crown rot, especially in fruits produced in low winter temperatures (Gowen, 1995).

2.5.1 Sources of Crown Rot Disease Inoculum

Flower part and the last bunch bract of the banana fruit are considered as good sources of inoculum during bunch growth and development (De Lapeyre and Mourichon, 1997). The crown rot pathogens sporulate on senescent flower parts and leaf debris in the plantation.

These spores are capable of invading freshly cut wounds (Barkai-Golan, 2001). Their spatial position makes them prime areas for bunch contamination during senescence. Decaying leaves and the male flower part remain the most important inoculum sources for *Colletotrichum musae* and *Fusariu*m spp. In plantations where deflowering is carried out, there is significant reduction in the amount of conidia present (De Lapeyre and Mourichon, 1997). Finlay *et al*. (1992) reported that, infection of the stalk or crown region of the banana bunch in the field may be sufficient to initiate rot development irrespective of the amount of inocula transferred unto the wounded

surfaces.

2.5.2 Mode of Crown Rot Disease Infection

Contamination of the banana fruits, stalk and the crown region by pathogenic fungi usually occur in the field. In the mature stage of the banana fruit, its tough skin protects it against fungal diseases. In banana plantations, rain plays a greater role in the dissemination of conidia as substantial rainfall correlated with greater spore release (Fitzell and Peak, 1984). Wind is also known to spread spore to developing hands. In packing house operations, infection of banana hands occurs in the dehanding tank (Eckert, 1990). Dehanding creates a weak spot for crown rot fungi to infect. The spores of the crown rot fungi are carried along to the packing house on the surface of fruits and may remain on packed fruits even after treatment (Dadzie, and Orchard, 1997). In some cases spores, can be drawn into freshly cut crown tissues up to a distance of 5-7mm. These spores may germinate and develop as deep-seated infections beyond the reach of chemical during treatments (Gowen, 1995).

2.5.3 Symptoms of Crown Rot Disease

Symptoms of crown rot as shown in Plate 2-1 below are characterized by softening and blackening of tissues at the cut crown surface (Ploetz *et al*., 1994). A greyish white, pink or white mold may appear on the cut crown surface at the early stages of development (Snowdon, 1990). Infected tissues turn black and the rot may advance into the finger stalk and ultimately the pulp (Lassois *et al*., 2008). In severe conditions, the finger stalk becomes weak and detaches (Win *et al*., 2007). The development of the disease also stimulates rapid ripening of the fruit and affects the quality of the fruit resulting in significant economic losses (Slabaugh and Grove 1982).

Plate 2-1: A banana hand showing signs of crown rot disease

2.5.4 Control of Crown Rot Disease

Control of crown rot usually starts in the field with regular removal of leaf trash. Proper field sanitation can greatly reduce the number of crown rot fungi spores present. Good cultural packing practices could be used to reduce crown rot incidence. Rotting fruits and plant waste materials should be properly disposed off (Dadzie and Orchard, 1997). Also the use of sharp knife for dehanding reduces the level of ragged cut which makes the crown

surface prone to fungi infection. Finally, post-harvest treatment of fruits with appropriate fungicide is essential (Win *et al*., 2007).

3.0 MATERIALS AND METHOD

3.1 FIELD SURVEY

A preliminary survey was conducted with market women to identify important banana producing areas in the Ashanti region. Information gathered from the Ministry of Food and Agriculture, Kumasi Regional and District offices together with the outcome of the preliminary survey were used in selecting appropriate districts covered in this work. On the basis of this, eight districts within the region were selected for the study. The survey was conducted between April to July, 2008.

3.1.1 Questionnaire Construction

A semi-structured questionnaire was used to assess the requisite information needed. Questionnaire design was targeted at farming and postharvest practices carried out on the farm aimed at reducing disease incidence both on-field and in storage. The data collection covered the following sections: bio-data of respondents, location, production practices, postharvest operations and farmers' knowledge on diseases and pests occurrences.

3.1.2 Sampling Area

Sampling was done in the eight selected districts namely; Asante Akim South, Asante Akim North Municipality, Ejisu-Juabeng Municipality, Sekyere East, Sekyere South, Mampong Municipality, Kwabre East and Offinso South all in the Ashanti Region. Areas with high banana production were identified and used as sampling location.

3.1.3 Questionnaire Administration

Interviews using semi-structured questionnaires were administered to farmers engaged in banana production in selected districts randomly. By the nature of the farming systems

employed and the difficulty in getting farmers engaged in banana mono-crop in these farming areas, farmer selection was rather based on those who cultivated banana in combination with other staple food crops or tree crops. Semi-structured questionnaires were administered to fifty-six (56) farmers from the selected sampling locations within the eight selected districts.

3.1.4 Statistical Analysis

Data collected from all sampling locations were analyzed using the Statistical Package for the Social Scientist (SPSS) version 16. Descriptive statistics were the statistical tools employed in the analysis. The data output were presented in tables and graphs (pie and bar charts).

3.2 LABORATORY EXPERIMENTS

The laboratory experiments were carried out in the Plant Pathology Section of the Crops Research Institute (CRI) of Council for Scientific and Industrial Research (CSIR), Fumesua between May to September, 2008.

3.2.1 Preparation of Growth Medium (Potato Dextrose Agar)

When available, 39g of Potato Dextrose Agar (PDA) (Oxoid CM0139, Hamphire, England) was weighed and suspended in 1litre of distilled water, stirred to obtain a uniform mixture and autoclaved at 121^{o}C for 15 minutes. The resulting mixture was dispensed into 9mm diameter petri dishes (autoclaved) when cooled. The poured medium is stored at 4^{o}C and used when needed.

When imported PDA is not available, the medium was prepared using fresh Irish potato, glucose and agar. In this case, 200g freshly chopped potatoes was boiled and distilled water added to make a fine suspension of one litre. Twenty grams of agar and 15g of glucose was added to the suspension. The resultant mixture was autoclaved at 121^{o}C for 5mins. The resultant mixture was allowed to cool, dispensed into sterile petri dishes and stored at 4^{o}C and used when required.

3.2.2 Amending of PDA

Amendment of PDA was carried out using a broad spectrum antibiotic, Ampicillin (250mg). Two capsule of Ampicillin was dissolved in 2ml of autoclaved distilled water and added to 500ml molten PDA. This was gently shaken to obtain a fine mixture before pouring was done.

3.2.3 Sources of Disease Tissues

Crown rot infected banana hands of Medium Cavendish variety were collected from selected locations namely Konongo, Agogo, Juaso, Obogu, Ejisu, Effiduase, Agona, Ninten, Kofiase, Mamponteng and Offinso in the eight districts under study. Hands showing severe crown rot disease were selected and used for the work.

3.2.4 Isolation of Fungal Organisms

Diseased hands were carefully washed under running tap water and diseased tissues were aseptically removed from advancing edges of the rot. Tissues were then cut into smaller pieces and surface sterilized with 0.5% of Sodium hypochlorite (NaOCl) solution for 5

minutes. These were then rinsed with sterile distilled water to remove traces of the bleaching agent used. The procedure was repeated again. Final washing was done under a hood. Resulting tissues were evenly spread out in a plate and allowed to dry.

Pieces of the dried tissues were aseptically removed and placed gently on a poured PDA plate. A five-point plating was done. Plated dishes were sealed off with paraffin tapes and were all labeled accordingly. The plated samples were sent to the incubation room and kept under room temperature. The samples were observed daily until fungi growths from the plated tissues were observed.

Fungi growths from the plated tissues were examined at the end of the incubation period (1-3 days). A three to five day old cultures showing different fungi colonies were selected for further studies. Agar plugs (5mm diameter) were taken from the growing tips of different fungi colonies observed, using a 5mm cork borer, and then transferred unto new plates. Plugs were placed downwards with the growing surface touching the PDA. Further purification of isolates were carried out through subculturing to obtain pure cultures of each fungal isolated.

3.2.5 Identification of Fungal Organisms

Pure cultures of individual fungal isolates (14 day old) were critically examined and identified. Colony identification was based on colony characteristics such as colour and texture of mycelia and type of pigmentation. Microscopic characteristics of spores such as shape and colour were depended on in identifying the fungal isolates based on descriptions of Holliday (1995) and Mathur and Kongsdal (2003).

3.3 PATHOGENICITY TEST

3.3.1 Experiment One: Individual Isolate Inoculation

Isolates of individual fungi maintained on PDA for one week were used in the inoculation experiments. Healthy bunch of banana were dehanded aseptically using a sharp scalpel blade. Hands from the middle portion of the bunch were selected for uniformity and used. The hands were next disinfected using 5% Sodium hypochlorite solution. The disinfected hands were washed with sterile distilled water and dried in a sterile hood. Wounds were created in the disinfected crowns using a 5mm sterile cork borer. Discs (5mm in diameter) of each of the fungal isolates listed below were used as inoculum to plug the wounds created in the crowns of the hands. Controls were set using hands with crown surface intact and no agar plug applied. Inoculated hands and the controls were incubated at room temperature. Fungal isolates used in the inoculation studies included:

i. *Botryodiplodia theobromae* ii. *Colletotrichum gloeosporioides*

iii. *Fusarium semitectum* iv. *Aspergillus flavus*

v. *Aspergillus niger* vi. *Aspergillus terreus*

3.3.2 Experiment Two: Combined Inoculation of Primary Pathogens

In this experiment, three fungal species *Botryodiplodia theobromae, Fusarium semitectum and Colletotrichum gloeosporiodes* which were the pathogens that caused crown rot and

were successfully re-isolated in experiment one were used. Further treatment combinations of the fungal isolates as presented below, were inoculated into healthy crowns singly or in combinations and incubated at room temperature. Fungal isolates used in the inoculation studies are as follows:

i. *Botryodiplodia theobromae* ii. *Colletotrichum gloeosporioides*

iii. *Fusarium semitectum* iv. *Botryodiplodia theobromae* + *Colletotrichum gloeosporiodes*

v. *Botryodiplodia theobromae* + *Fusarium semitectum* vi. *Colletotrichum gloeosporiodes* + *Fusarium semitectum* vii. *Botryodiplodia theobromae* + *Colletotrichum gloeosporioides* + *Fusarium semitectum*

To complete Kock's postulate, re-isolation was carried out from the inoculated crowns that developed the rot. Organisms isolated were compared with those inoculated on PDA to establish their similarity.

3.4 CROWN ROT ASSESSMENT

Crown rot disease assessments were carried out on inoculated banana hands for a period of 10 days. The extent of rot was estimated by measuring the length of the rot from the crown surface to the advancing edge of the disease development. Crown rot index scale of 0-4 by Sarananda and Wijeratnam (1994) was used to score for disease severity in Table 3.1 below.

Table 3.1: Crown rot disease index by Sarananda and Wijeratnam (1994)

Crown Rot Score	Description
0	No rot present on the crown surface
1	¼ or 25% of the crown surface affected by the rot
2	½ or 50% of the crown surface affected by the rot
3	3/4 or 75% of the crown surface affected by the rot
4	Entire crown surface affected by rot and extending to the finger stalk or pulp

3.5 EXPERIMENTAL DESIGN

A Completely Randomized Design (CRD) was the experimental design used. Experiments were replicated three times. The different fungal isolates served as treatments.

3.6 STATISTICAL ANALYSIS

Data collected was subjected to statistical analysis using Analysis of Variance (ANOVA). Statistical package used was Statistix version 9. Testing for differences between means was at 5% level (P = 0.05).

4.0 RESULTS

This chapter presents the findings of the questionnaires elicited from the respondents who comprised of banana farmers randomly selected from the districts. It also contains findings from the laboratory experiments conducted on the crown rot diseased banana samples collected from the various locations.

4.1 FIELD SURVEY

4.1.1 Background Information on Farmers

A total of 56 farmers were interviewed to ascertain their background information, production practices, postharvest techniques employed and general knowledge on crown

rot disease of banana. Data on the sex of the respondent in the districts showed that males dominated in seven out of the eight districts except for Asante Akim South District where females (57.5%) dominated males (42.9%) in farming of banana. However, in the Mampong Municipality farmers interviewed were all males (100%). In the rest of the districts, males dominated females in farming (Figure 4.1).

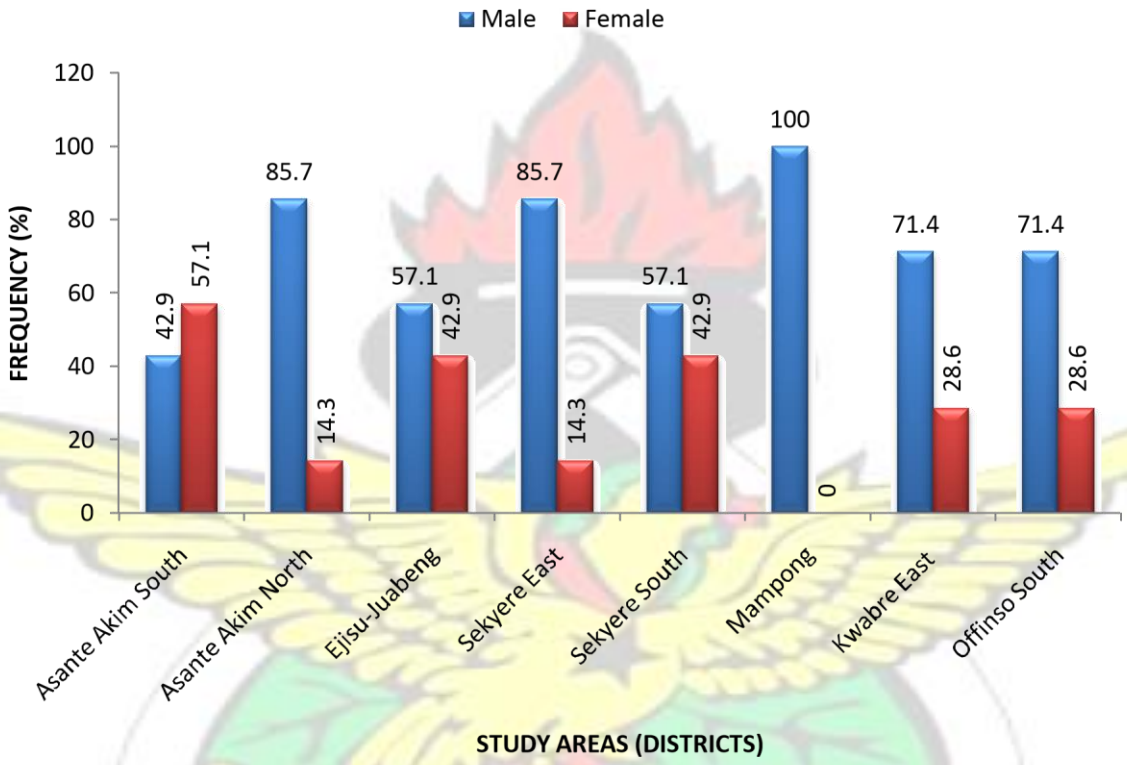


Figure 4.1: Sex of respondents

Age distribution differed from district to district as indicated in Table 4.1 below. Most of the respondents were in the age range of 40-49 years (30.9%), 60 years and above (29.2%), 50-59 years (23.6%), 30-39 years (12.8%) while 3.5% were in the range of 2029 years. Farmers aged 60 years and above ranged from 42.9% in Asante Akim North Municipality, Sekyere South and Kwabre East Districts respectively to 57.1% in Asante

Akim South. Farmers between the ages of 50-59 years ranged from 42.9% in Kwabre East to 57.1% in Offinso South Districts. In addition, farmers aged between 40-49 years ranged from 42.8%, in Ejisu-Juabeng Municipality, 42.9% in Sekyere South to 66% in Sekyere East District.

Table 4.1: Age distribution of farmers

	Age Range (years)					
District / Municipality	**20-29**	**30-39**	**40-49**	**50-59**	**60 and above**	**Total**
Asante Akim South	-	-	28.6	14.3	57.1	100
Asante Akim North	14.3	28.5	14.3	-	42.9	100
Ejisu-Juabeng	-	-	42.8	28.6	28.6	100
Sekyere East	-	16.7	66.6	16.7	-	100
Sekyere South	-	-	42.9	14.2	42.9	100
Mampong	14.3	28.6	28.6	14.3	14.3	100
Kwabre East	-	14.2	-	42.9	42.9	100
Offinso South	-	14.3	28.6	57.1	-	100
Total	**3.5**	**12.8**	**30.9**	**23.6**	**29.2**	**100**

On the level of education, majority of the farmers interviewed had basic education (60.7%), 23.2% had no formal education, 8.9% had tertiary education whiles 7.1% had secondary education. Ejisu-Juabeng Municipality and Sekyere East Districts recorded the highest in basic education (71.4%) respectively. Asante Akim North Municipality on the other hand recorded the highest in no formal education (42.9%). Offinso South recorded

the highest in secondary education (28.6%). However, 14.3% of the farmers in Asante Akim South, Sekyere East, Sekyere South, Mampong Municipality and Kwabre East Districts had education up to tertiary level (Table 4.2).

Table 4.2: Educational level of respondents

District/ Municipality	No formal education	Basic education	Secondary	Tertiary	Total
Asante Akim South	14.3	57.1	14.3	14.3	100
Asante Akim North	42.9	57.1	-	-	100
Ejisu-Juabeng	14.3	71.4	14.3	-	100
Sekyere East	14.3	71.4	-	14.3	100
Sekyere South	28.6	57.1	-	14.3	100
Mampong	28.6	57.1	-	14.3	100
Kwabre East	28.6	57.1	-	14.3	100
Offinso South	14.3	57.2	28.6	-	100.1
Total	**23.2**	**60.7**	**7.1**	**8.9**	

In addition to farming, petty trading, dress making, transportation, palm wine taping and agro-chemical products retailing were the other economic activities that occupy some of the farmers.

4.2.2 Production Practices Carried Out on Farms

From Table 4.3 below, mixed cropping farming system dominated banana production in most farms visited. Eighty-two percent of the farmers practiced mixed cropping with food crops such as cassava, plantain, cocoyam, maize and vegetables such as garden eggs, tomato, pepper and okra. Sixteen percent of the farmers practiced intercropping with tree

crops such as cocoa, oil palm and citrus. However, 1.8% of the farmers planted banana as a sole crop. Mixed cropping with food crops was the major farming system practiced in seven of the districts; Asante Akim South, Asante Akim North Municipality , Ejisu-Juabeng Municipality, Sekyere East, Sekyere South, Kwabre East and Offinso South Districts except for Mampong Municipality where intercropping with tree crops such as cocoa, oil palm and citrus (71.4%) dominated. Banana monocrop system was found only in the Sekyere East District (14.3%).

Table 4.3 Farming systems practiced by farmers

District/ Municipality	**Mono-cropping**	**Mixed cropping**	**Intercropping**	**Total**
Asante Akim South	-	100	-	100
Asante Akim North	-	100	-	100
Ejisu-Juabeng	-	100	-	100
Sekyere East	14.3	85.7	-	100
Sekyere South	-	100	-	100
Mampong	-	28.6	71.4	100
Kwabre East	-	71.4	28.6	100
Offinso South	-	71.4	28.6	100
Total	**1.8**	**82.1**	**16.1**	**100**

Eighty-four percent of the farmers cultivated the local banana variety “asante kwadu” while 16% grew the improved variety, Medium Cavendish variety.

Sixty-seven percent of the farmers interviewed cultivated between 1-5 acres, 16.3% between 6-10 acres, 12.2% cultivated more than 10 acres whereas 4.1% cultivated less than an acre of land (Figure 4.2).

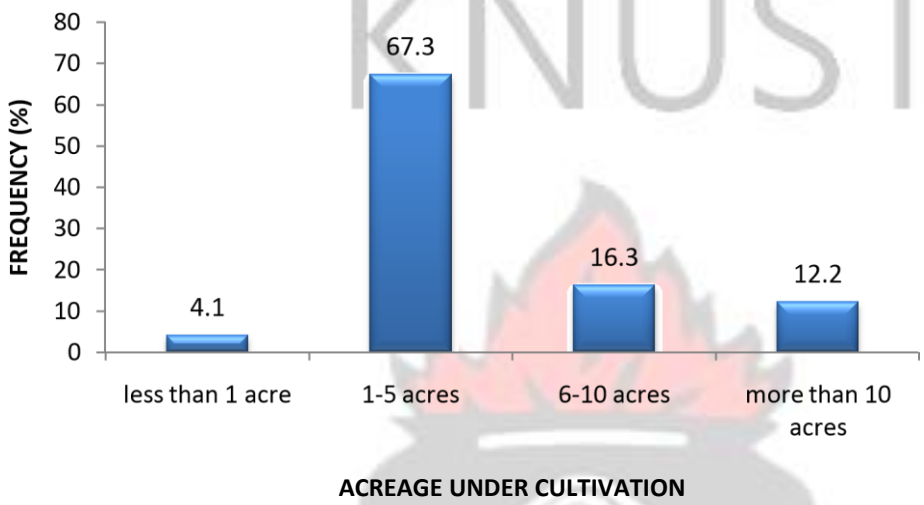


Figure 4.2: Acreage of land under cultivation

Interestingly, banana suckers were the most common planting material used in farm establishment. Sixty-four percent of the farmers obtained suckers from their own farm, 26.4% from friends' farm, and 7.5% from family farm whilst 1.9% obtained suckers from the market (Figure 4.3).

1.9

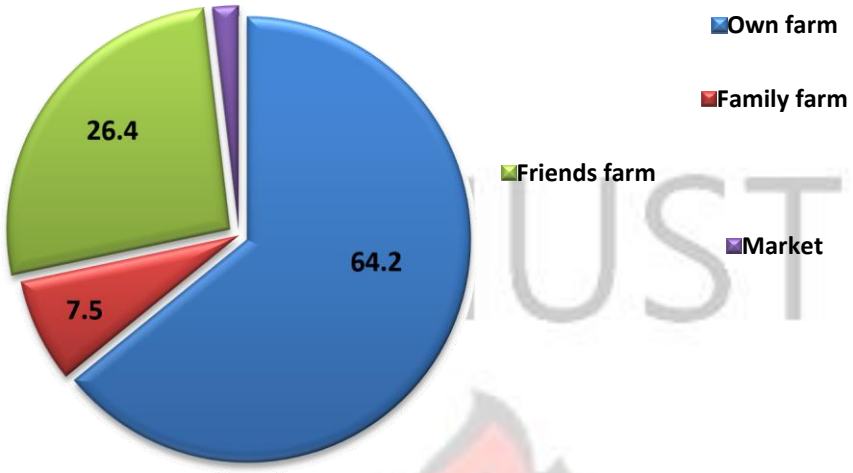


Figure 4.3: Sources of planting material used in farm establishment

4.2.3 Cultural Practice Carried Out on Farm

Cultural practices carried out on the farm included weed control, mulching, pruning, diseases and pests control as summarized in Table 4.4.

Table 4.4: Summary of cultural activities carried out on the farms

Activity	Practiced	Do not practice	Total
Weed control	98.2	1.8	100
Mulching	25.0	75.0	100
Pruning	62.5	37.5	100
Diseases and pests control	23.2	76.8	100

Farmers in Asante Akim South did not practiced both mulching and pests and diseases control. In Mampong Municipality, mulching was not practiced (Appendix A4).

4.2.3.1 Weed control

Majority of farmers (98.2%) controlled weeds on their farm whilst 1.8% did not (Table 4.4). Most farmers (53.6%) weeded their farm three times in a year, 37.5% two times in a year, 5.4% once a year whiles 1.8% controlled weeds four times in a year and as and when weeds appeared respectively (Table 4.5). Farmers in Asante Akim South, EjisuJuabeng Municipality, Mampong Municipality, Kwabre East and Offinso South controlled weeds thrice in a year. However, Asante Akim North Municipality, Sekyere East and Sekyere South controlled weeds twice in a year. Weeding was manually done in all the districts visited.

Table 4.5: Frequency of weeding on the farms visited

	Weeding frequency (per year)					
District / Municipality	**Once**	**Twice**	**Thrice**	**Four times**	**As and when required**	**Total**
Asante Akim South	-	28.6	57.1	14.3	-	100
Asante Akim North	-	57.1	42.9	-	-	100
Ejisu-Juabeng	-	28.6	71.4	-	-	100
Sekyere East	28.6	42.9	28.6	-	-	100
Sekyere South	14.3	57.1	28.6	-	-	100
Mampong	-	42.9	57.1	-	-	100
Kwabre East	-	28.6	71.4	-	-	100
Offinso South	-	14.3	71.4	-	14.3	100
Total	**5.4**	**37.5**	**53.6**	**1.8**	**1.8**	**100**

4.2.3.2 Mulching

Few farmers (25%) practiced mulching while majority (75%) did not (Table 4.4). Materials commonly used in mulching farms included dry banana leaves (72.7%), dry weeds (18.2%) and palm fronds (9.1%) as shown in Table 4.6 below.

Table 4.6: Mulch materials mostly used on the farm

District / Municipality	Dry weeds	Dry banana leaves	Palm fronds	Total
Asante Akim South	-	-	-	-
Asante Akim North	100	-	-	100
Ejisu-Juabeng	-	-	100	100
Sekyere East	-	100	-	100
Sekyere South	-	50	50	100
Mampong	-	-	-	-
Kwabre East	100	-	-	100
Offinso South	-	100	-	100
Total	**18.2**	**72.7**	**9.1**	**100**

4.2.3.3 Pruning operation

Most of the farmers (62.5%) pruned their crops whiles 37.5% did not (Table 4.4). pruning was practiced in all the eight districts under study (Appendix A4). The main materials normally pruned included dry and diseased banana leaves (100%). Pruning was done to improve aeration and to minimize the spread of diseases. However, pruning was routinely done during harvesting. The pruned materials were used as mulch materials.

4.2.3.4 Diseases and pests control

Few farmers (23.2%) controlled pests and diseases on their farm while the majority (76.8%) did not (Table 4.4). Farmers in six out of the eight districts controlled diseases and pests whereas Asante Akim South and Mampong Municipality did not. Common pests identified on most farms included rodents, birds, banana weevils, white flies and ants. Sigatoka and Fusarium wilt were the most serious diseases observed. Most of the farmers (70%) controlled diseases and pests by destroying and burying affected plants whereas few farmers (30%) did routine spraying with agro-chemicals such as Ceres (Dimethoate 400g/l EC), Sunpyrifos 48% EC (Chlorpyrifos-ethyl 480g/l) and Lamdacot (Lambdacyhalothrin 2.5% EC) (Table 4.7).

Table 4.7: Control measures employed in disease and pest management

District / Municipality	**Routine spraying**	**Destroying and burying affected plants**	**Total**
Asante Akim South	-	-	-
Asante Akim North	66.7	33.3	100

Ejisu-Juabeng	20	80	100
Sekyere East	42.9	57.1	100
Sekyere South	50	50	100
Mampong	50	50	100
Kwabre East	-	100	100
Offinso South	-	-	-
Total	**30**	**70**	**100**

4.2.3.5 Sucker and bunch management

From Table 4.8 below, de-suckering was practiced in six districts except for Sekyere South and Mampong Municipality. De-suckering was done to remove excess suckers at a stand and to enhance better plant growth. De-budding was practiced in Sekyere South and Offinso South. It was done to remove the male inflorescence and to reduce pests' damage to fruits.

Table 4.8: Sucker and bunch management practiced on the farm

District / Municipality	**De-suckering**		**De-budding**	
	Yes	**No**	**Yes**	**No**
Asante Akim South	71.4	28.6	-	100
Asante Akim North	42.9	57.1	-	100
Ejisu-Juabeng	28.6	71.4	-	100

Sekyere East	42.9	57.1	-	100
Sekyere South	-	100	100	-
Mampong	-	100	-	100
Kwabre East	33.3	66.7	-	100
Offinso South	100	-	100	-
Total	**41.5**	**58.5**	**25**	**75**

4.2.4 Harvesting and Postharvest Operations

Majority of farmers (96.2%) usually harvested the bunch in the unripe stage whiles few farmers (3.8%) harvest at the ripe stage (Figure 4.4).

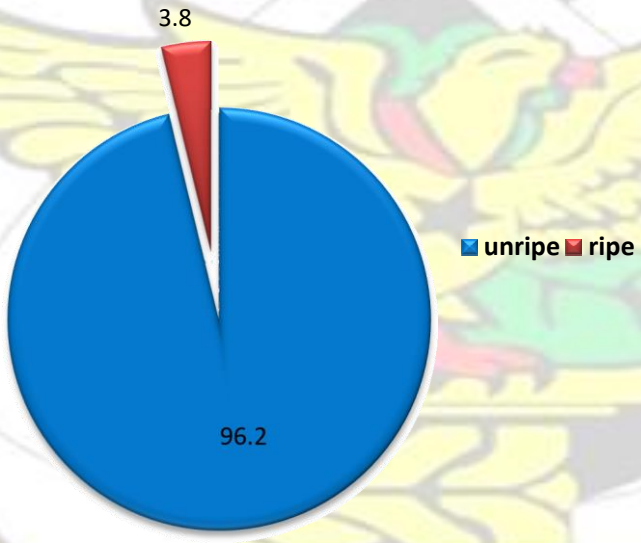


Figure 4.4: Stage at which bunches are harvested

The most harvesting index used by farmers in determining bunch maturity were visual observation (94.4%) and calendar date (5.6%). Machete was the most common harvesting tool used by the farmers.

Majority of the respondents conveyed whole bunches (82.7%) to the market, 15.4% conveyed dehanded bunches while 1.9% convey both whole bunches and dehanded bunches (Table 4.9).

Table 4.9: State in which harvested fruits were conveyed to market

District / Municipality	Whole bunch	Dehanded bunch	Both	Total
Asante Akim South	85.7	14.3	-	100
Asante Akim North	100	-	-	100
Ejisu-Juabeng	100	-	-	100
Sekyere East	71.4	28.6	-	100
Sekyere South	66.7	16.7	16.7	100
Mampong	100	-	-	100
Kwabre East	66.7	33.3	-	100
Offinso South	82.7	15.4	-	100
Total	**82.7**	**15.4**	**1.9**	**100**

4.2.5 Knowledge on Rot Diseases

About 40% of the farmers reported they had some of their fruits rotting in storage while 60% did not experience rots in storage (Appendix A5). Fruit rots observed were described as dark brown to black in nature occurring at the tips of fruits, crown regions and in some cases as black spots on the fingers. Control measures employed included regular checking of stored fruits (50%) and burying of rotten fruits (22.2%). However, few farmers (27.8%) had no knowledge on storage disease (Table 4.10).

Table 4.10: Control measures employed in checking rots in storage

District / Municipality	**Regular checking**	**burying of rotten fruits**	**No knowledge on storage disease**	**Total**
Asante Akim South	100	-	-	100
Asante Akim North	100	-	-	100
Ejisu-Juabeng	20	20	60	100
Sekyere East	100	-	-	100
Sekyere South	33.3	66.7	-	100
Mampong	-	-	100	100
Kwabre East	-	-	100	100
Offinso South	-	100	-	100
Total	**50**	**22.2**	**27.8**	**100**

4.2.6 Constraints to Production

Some of the challenges faced by the farmers in banana production included inadequate funds for farm expansion, high cost of agricultural inputs, prevalence of Sigatoka and Fusarium Wilt diseases, lack of market for harvested fruits, poor road network and lastly, the high premium placed on the cultivation of plantain.

4.3 LABORATORY WORK

4.3.1 Isolation of Fungal Isolates

Isolation of crown rot fungal pathogens was carried out on banana samples showing severe symptoms of crown rot disease collected from the eight districts under study. Isolation of fungi associated with the crown rot disease complex from diseased banana crowns was conducted between May to September, 2008.

Table 4.11 shows the frequency of isolation of fungal species from 120 diseased tissues taken from advancing edge of the rot. *Botryodiplodia theobromae* recorded the highest occurrence in Asante Akim South (59%), Asante Akim North Municipality (54%) and Offinso South (50%). *Fusarium semitectum* also recorded the highest frequencies in Mampong Municipality (47%) and Kwabre East (31%) districts. *Colletotrichum gloeosporioides* also recorded the highest frequency of occurrence in Ejisu-Juabeng Municipality (29%), Sekyere East (32%) and Sekyere South (37%) districts. *Aspergillus flavus* was mostly isolated from Sekyere South (26%) whiles *Aspergillus niger* was mostly

isolated from Kwabre East (23%) districts. *Aspergillus terreus* was isolated only from two districts namely Ejisu-Juabeng Municipality (10%) and Sekyere South (11%).

Table 4.11: Frequency of isolation of fungal species associated with crown rot disease

	Organisms Isolated					
District/ Municipality	*B. theobromae*	*F. semitectum*	*C. gloeosporioides*	*A. flavus*	*A. niger*	*A. terreus*
Asante Akim South	**59**	-	29	12	-	-
Asante Akim North	**54**	8	32	6	-	-
Ejisu-Juabeng	-	24	**30**	22	14	10
Sekyere East	26	18	**33**	10	13	
Sekyere South	19	-	**37**	26	7	11
Mampong	7	**47**	33	7	6	-
Kwabre East	15	**31**	23	8	23	-
Offinso South	**50**	15	30	5	-	-

Table 4.12: Occurrence of fungal pathogens associated with crown rot disease

District / Municipality	**Fungal pathogens Isolated**
Asante Akim South	*B. theobromae, C. gloeosporioides*
Asante Akim North	*B. theobromae, C. gloeosporioides, F. semitectum*
Ejisu-Juabeng	*C. gloeosporioides, F. semitectum*
Sekyere East	*B. theobromae, C. gloeosporioides, F. semitectum*
Sekyere South	*B. theobromae, C. gloeosporioides*
Mampong	*B. theobromae, C. gloeosporioides, F. semitectum*
Kwabre East	*B. theobromae, C. gloeosporioides, F. semitectum*
Offinso South	*B. theobromae, C. gloeosporioides, F. semitectum*

Fungal pathogens isolated and identified from the decaying crowns were *Botryodiplodia theobromae, Colletotrichum gloeosporioides* and *Fusarium semitectum. C. gloeosporioides* was frequently isolated from all eight districts, *B. theobromae* from seven districts and *F. semitectum* from five districts out of the eight districts (Table 4.12).

Table 4.13: Fungal Species that did not cause crown rot

District / Municipality	**Fungal pathogens Isolated**
Asante Akim South	*A. flavus*
Asante Akim North	*A. flavus*
Ejisu-Juabeng	*A. flavus, A. niger, A. terreus*
Sekyere East	*A. flavus, A. niger*
Sekyere South	*A. flavus, A. niger, A. terreus*
Mampong	*A. flavus, A. niger*
Kwabre East	*A. flavus, A. niger*
Offinso South	*A. flavus*

Aspergillus flavus, Aspergillus niger and Aspergillus terreus were isolated and identified but did not cause crown rot. *A. flavus* was isolated from all the eight districts, *A. niger* from five districts and *A. terreus* from two districts out of the eight districts (Table 4.13).

4.3.2 Characteristics of Fungal Isolates Associated with Crown Rot Disease

Table 4.14: Colony and Microscopic Characteristics of Fungal Isolates

Fungal Isolate	Characteristics	
	Colony	**Microscopic**
1. *Botryodiplodia theobromae*	The fungus had fluffy mycelia and grew rapidly on PDA. Young cultures were snow-white in nature, turning grayish with time. Older cultures turned black and produced pycnidia (black projections on culture) which were visible to the naked eye (Plate: 4-1).	Spores were big and oval. Mature spores were dark and 1-septate (single septum) when viewed under the microscope (Plate: 4-2).
2. *Fusarium semitectum*	The fungus was readily distinguished from other Fusaria by its soft woolly hairs and dense aerial mycelia. The colony appeared to be orange turning to brown as the culture ages (Plate: 4-3).	Spores were mostly curved or spindle-shaped and had a foot cell. Spores were 3- to 7-septate under microscope (Plate: 4-4).
3. Colletotrichum gloeosporioides	The fungus had very little mycelia and grew slowly on PDA. Old cultures were dull white to shiny dull orange (Plate: 4-5).	Spores were 1-celled and cylindrical with rounded ends under microscope (Plate: 4-6).
4. Aspergillus flavus	The fungus was effuse in nature and grew rapidly on potato dextrose agar. Old cultures were olive to lime green (Plate: 4-7).	Spores produced were numerous, globose to subglobose and smooth in nature under microscope (Plate: 4-8).
5. Aspergillus niger	The colony on PDA was initially white and quickly turned black as conidial production started. Its growth produced radial fissures in the agar (Plate: 4-9).	Conidia present were numerous, globose and very rough. Immature spores were brown and older spores turn black (Plate: 4-10).

6. Aspergillus terreus	It had a moderate to rapid growth rate on potato dextrose agar. Colony was yellowish-brown to brown. The colony became finely granular as conidial production started (Plate: 4-11).	Conidia produced were globose and smooth in nature. Spores were dark brown under microscope (Plate: 4-12).

Plate Characteristics of Fungal Isolates

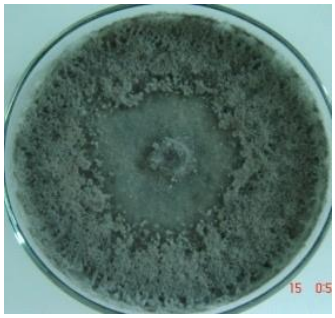


Plate 4-1: Culture of *B. theobromae*

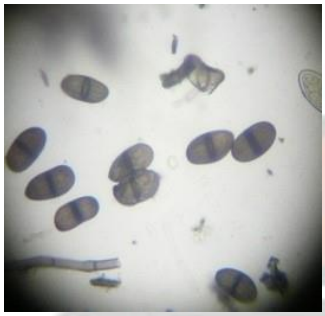


Plate 4-2: Mature spores of *B. theobromae*

Plate 4-3: Culture of *F. semitectum*

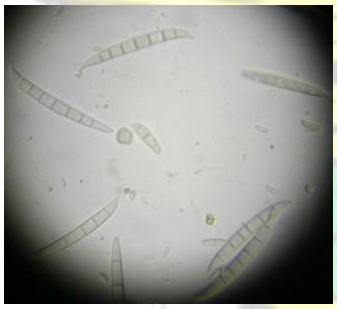


Plate 4-4: Mature spores *F. semitectum*

Plate 4-5: Culture of *C. gloeosporioides*

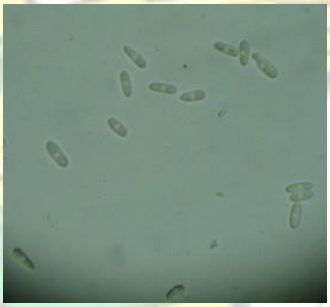


Plate 4-6: Mature spores of *C. gloeosporioides*

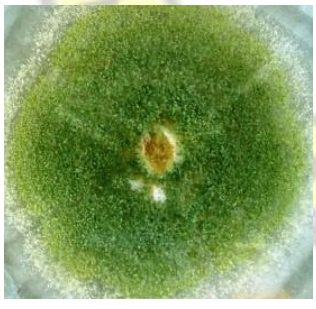


Plate 4-7: Culture of

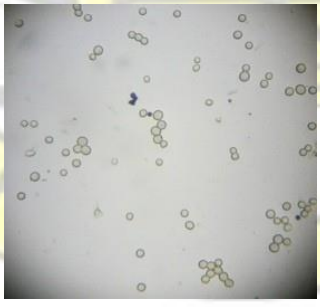


Plate 4-8: Mature spores

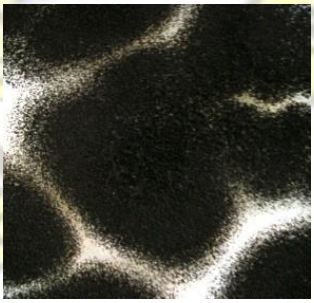


Plate 4-9: Colonies of *A.*

A. flavus *A. flavus* *niger*

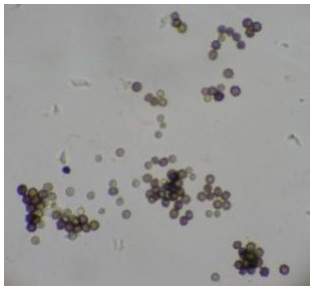


Plate 4-10: Mature and immature spores of *A. flavus*

Plate 4-11: Colonies of *A. terreus*

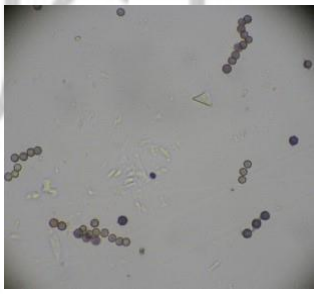


Plate 4-12: Mature spores of *A. terreus* *A. niger*

4.3.3 Pathogenicity Test

The outcome of the pathogenicity test involving the six fungal isolates is summarized in Table 4.15 below. *B. theobromae, C. gloeosporioides and F. semitectum* caused crown rot disease when they were inoculated singly into crown surfaces of healthy banana hands. These fungi grew rapidly to cover the entire crown region, caused the disease on the crown region and spread towards the finger stalks of the hand. These fungi were successfully re-isolated from the diseased crown tissues at the end of an incubation period of 10days.

Aspergillus flavus, Aspergillus niger and *Aspergillus terreus* were also inoculated into healthy crown tissues and grew to cover the crown surface. However, they did not cause the disease and were not successfully re-isolated from the diseased crown tissues.

Table 4.15: Pathogenicity test of six fungal isolates

Fungal isolates	**Crown rot symptoms**	**Re-isolation**

B. theobromae	+	+
C. gloeosporioides	+	+
F. semitectum	+	+
A. flavus	+	-
A. niger	+	-
A. terreus	+	-
Control	+	-

(+) successful re-isolation, (-) unsuccessful re-isolation ,

In the combined inoculation experiment where more than one pathogen was used, combinations of *B. theobromae*, *C. gloeosporioides* and *F. semitectum* were found to have caused the disease and were successfully re-isolated. In all cases, the pathogens involved were successfully re-isolated (Table 4.16).

Table 4.16: Pathogenicity test of three primary pathogens and their combination

Fungal pathogen	**Crown rot disease**	**Re-isolation**	**Confirmation**
Botryodiplodia theobromae	++	+	Present
Colletotrichum gloeosporioides	++	+	Present
Fusarium semitectum	++	+	Present
B. theobromae + C. gloeosporioides	++	+	Present
B. theobromae + *F. semitectum*	++	+	Present

C. gloeosporioides + *F. semitectum*	++	+	Present
B. theobromae + C. gloeosporioides + *F. semitectum*	++	+	Present
Control (no inoculum)	-	-	-

(++) symptoms of crown rot disease (+) successful re-isolation

Crown rot disease assessment was conducted on inoculated hands. Disease severity was determined through a disease severity index scale of 0-4 (Table 3.1). From Table 4.17 below, the individual fungi and their respective combinations showed a gradual increase in disease severity over the storage period. *C. gloeosporioides*, *B. theobromae* + *C. gloeosporioides* and *B. theobromae* + *C. gloeosporioides* + *F. semitectum* had a disease score of 4 representing 100% of crown area attacked in seven days after inoculation. *B. theobromae, C. gloeosporioides* + *F. semitectum*, *B. theobromae* + *F. semitectum* had a disease score of 4 eight days after inoculation. *F. semitectum* had a score of 3 (75% of crown area attacked) on the 8th day. However, the control had a disease score of 2 representing 50% of the crown area attacked on the 8th day after inoculation.

Table 4.17: Disease severity of inoculated fungal pathogens

Fungi pathogens	**Inoculation period (Days)**					
	3	**4**	**5**	**6**	**7**	**8**
B. theobromae	0.33	1.00	1.67	2.7	3.33	3.67
C. gloeosporioides	1.00	2.00	2.00	3.0	4.00	4.00

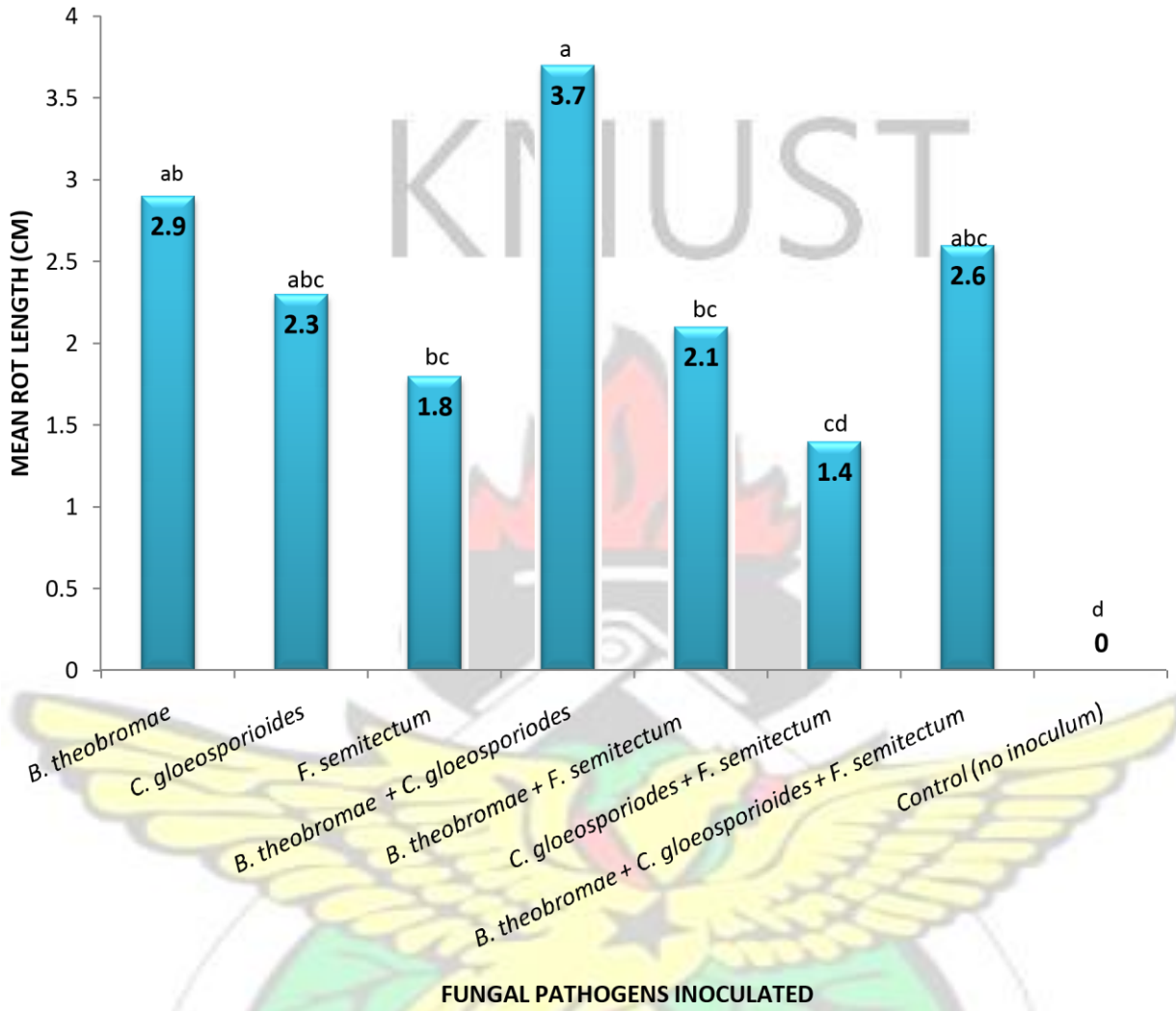
F. semitectum	1.00	1.33	1.33	2.3	3.00	3.33
B. theobromae + C. gloeosporiodes	0.67	1.00	2.00	3.0	4.00	4.00
B. theobromae + F. semitectum	0.67	1.67	2.33	2.7	3.67	3.67
C. gloeosporiodes + F. semitectum	1.00	1.33	1.67	2.3	3.33	3.67
B. theobromae + C. gloeosporioides + F. semitectum	1.00	1.33	2.00	3.0	4.00	4.00
Control (no inoculum)	0.00	0.00	1.00	1.00	1.00	2.00
Lsd $_{(0.05)}$	0.61	0.71	0.71	0.71	1.12	0.71

Differences were observed between the control treatment and *C. gloeosporioides, F. semitectum, B. theobromae + C. gloeosporioides, B. theobromae + F. semitectum, C. gloeosporioides + F. semitectum* and *B. theobromae + C. gloeosporioides + F. semitectum* ($P < 0.05$). *B. theobromae* was also statistically different from *C. gloeosporioides, F. semitectum, C. gloeosporioides + F. semitectum,* and *B. theobromae + C. gloeosporioides + F. semitectum* ($P < 0.05$) three days after inoculation.

The control treatment was significantly different from *B. theobromae, C. gloeosporioides, F. semitectum, B. theobromae + C. gloeosporioides, B. theobromae + F. semitectum, C. gloeosporioides + F. semitectum* and *B. theobromae + C. gloeosporioides + F. semitectum + B. theobromae*, Similarly, *C. gloeosporioides* was significantly different from *B. theobromae* and *B. theobromae + C. gloeosporioides* ($P < 0.05$) four days after inoculation.

Again, *B. theobromae + F. semitectum* was significantly different from *F. semitectum* and the control. The control was also different from *C. gloeosporioides, B. theobromae + C. gloeosporioides, B. theobromae + F. semitectum* and *B. theobromae + C. gloeosporioides + F. semitectum* ($P < 0.05$) five days after inoculation.

Statistically, there were significant differences between the control treatment and the other treatments (*B. theobromae, C. gloeosporioides, F. semitectum, B. theobromae + C. gloeosporioides, B. theobromae + F. semitectum, C. gloeosporioides, F. semitectum* and *B. theobromae + C. gloeosporioides + F. semitectum gloeosporioides*) on the 6^{th}, 7^{th} and 8^{th} day after inoculation ($P < 0.05$).



Note: Bars having the same letters are not significantly different (P>0.05).

Figure 4.6: Mean rot length caused by the fungal species

Figure 4.6 above shows the mean rot length caused by the three fungi and their combinations inoculated into crowns of banana hand. Inoculation involving *B. theobromae* + *C. gloeosporioides* gave the longest rot length of 3.7cm eight days after inoculation. This was followed by *B. theobromae* (2.9cm), *B. theobromae* + *C.*

gloeosporioides + F. semitectum (2.6cm), *B. theobromae + F. semitectum* (2.1cm), *C. gloeosporioides* (1.8), and *C. gloeosporioides + F. semitectum* (1.4cm). However, the control treatment which had no inoculum recorded no rot.

Statistically, there were significant difference ($P<0.05$) observed between the control and fungal treatments *B. theobromae, C. gloeosporioides, F. semitectum, B. theobromae, + C. gloeosporioides, B. theobromae + F. semitectum* and *B. theobromae + C. gloeosporioides + F. semitectum*. Significant differences ($P<0.05$) were also observed between *B. theobromae, + C. gloeosporioides* and *B. theobromae + F. semitectum, F. semitectum* and *C. gloeosporioides + F. semitectum*. Again, the difference observed between *B. theobromae and C. gloeosporioides + F. semitectum was* also significant ($P<0.05$).

5.0 DISCUSSION

5.1 SURVEY

5.1.1 Background Information on Farmers

From the results, it can be construed that more males were engaged in farming than females in the study areas. More males were engaged in the cultivation of cash crops like cocoa which are usually intercropped with banana. The study also revealed that farmers within the economically active age group (40 years and above) mostly dominated the farming profession. However, for Asante Akim South, Asante Akim North Municipality, Sekyere South and Kwabre East Districts, most of the farmers were aged 60 years and above. In these districts, older people in the society were mainly into farming. It could therefore be concluded that the youth in the districts visited were less interested in farming as a profession. Basic education was the main educational qualification of farmers in the eight districts visited. Asante Akim North Municipality, Sekyere South, Mampong Municipality and Kwabre East districts had a high proportion of the farmers having no formal education. Similar observation by Banful (1998) in most plantain production areas in the Ashanti Region indicated that most farmers were semiliterate with only primary level education. Extra economic activities engaged in by farmers in the districts included trading, dress making, transportation and palm wine taping. Farmers engage in these activities to supplement the income generated in the farming activity. KMA (2007) draft

report indicated that agriculture played a major economic role in employing many of the rural population in the Ashanti Region. Furthermore, Biederlack and Rivers (2009) similarly reported that the 2000 national population census showed that more than half of the country's workforce was directly engaged in agricultural activities.

5.1.2 Production Practices Carried Out on Farms

In most of the banana producing areas such as Asante Akim North Municipality, EjisuJuabeng Municipality, Sekyere East and South, Kwabre East and Offinso South Districts where farmers practiced mixed cropping system, staple food crops such as cassava, plantain, cocoyam, maize and vegetables including garden eggs, tomato, pepper and okra were mostly grown together with banana on any available piece of land to supplement the family's income. In the Mampong Municipality, Kwabre East and Offinso South Districts where intercropping farming system was used, tree crops such as cocoa, oil palm and citrus were the major crops grown together with banana. However, banana mono-crop system was only practiced in Sekyere East District. The survey revealed that most of the farmers preferred growing plantain and other food crops to banana even though the latter gave higher returns. This accounted for the proportion of farmers practicing mixed cropping and intercropping farming systems in many of the districts visited. A MoFA (2006) draft report associated mono-cropping systems with large-scale commercial farms. Typical example being Volta River Estate Limited which produces banana in commercial quantities and supplies the domestic, regional and international markets (MoFA, 2002). The local banana variety "Asante kwadu' dominated production owing to

the fact that it was well-adapted to the local condition and most preferred to the improved type, the Medium Cavendish variety. The study also revealed that between 1-5 acres (0.4-2 hectares) of land was commonly put under cultivation in most cropping systems. A comprehensive food security and vulnerability analysis report on Ghana showed that more than 90% of farm holdings were less than two hectares in size, yet they contribute about 80% of the country's total agricultural output (Biederlack and Rivers, 2009),. It was also observed that farmers mostly use banana suckers from ratoon fields for farm establishment because of its availability all year round. Almost all the farmers did not clean the suckers before planting. This practice also facilitates the transfer of disease pathogens from one location to the other.

5.1.3 Cultural Activities Practiced on the Farms

Weed control was done three times in a year in Asante Akim South, Ejisu-Juabeng Municipality, Mampong Municipality, Kwabre East and Offinso South. Weeding was manually done using the hoe for ground work and the machete for weed slashing. This practice by the farmers resulted in good farm sanitation, reducing the breeding place and survival of vectors that facilitate crown rot inoculum transfer from plant to plant and from one location to the other.

Mulching was done in six districts, namely Asante Akim North Municipality, EjisuJuabeng Municipality, Sekyere East and South, Kwabre East and Offinso South. Mulching was done using plant materials such as dried banana leaves, dry weeds and palm

fronds to either conserve soil moisture or to suppress weed growth. Mulching serves as a barrier to field infection where free living spores in the soil are prevented from being carried by rain or wind onto healthy banana plants. Where mulching is not done, the exposed soil may facilitate inoculum transfer to plants.

The survey, showed that pruning was carried out in all the eight districts. Dead and diseased banana leaves were the most common material pruned. De Lapeyre and Mourichon (1997) reported that crown rot fungi were very common on banana and decaying debris served as sporulating medium from which free living spores were disseminated through wind and water-splash. Also trash leaves hanging on the banana plant serve as a medium and secondary inoculum source for further bunch contamination. Palti (1981) in his studies on infectious crop diseases concluded that cultural practice such as pruning and subsequent destruction of crop debris had marked effect on the survival of most pathogens. In the study, farmers used these pruned materials (dead and disease leaves) as mulching materials to cover the bare soil. This practice carried out by the farmers rather enhances inoculum development through the provision of a good substrate suitable for fungal sporulation and subsequently providing an inoculum source for field contamination. Hence, the practice of pruning hanging trash and diseased leaves to prevent field infection rather enhanced disease build up in the field and ultimately influenced crown rot disease incidence in the study area.

Black Sigatoka and Fusarium wilt diseases were the most serious diseases encountered on the farm. Stover and Simmonds (1987) reported that Black Sigatoka disease was among the most devastating diseases affecting both the local and widely grown cultivars of banana in the West, Central and Eastern African. Stover (1986) also reported that these leaf diseases affected yield and production costs of the Cavendish variety in the tropics. Destroying affected plants and subsequently burying diseased materials as practiced by the farmers in controlling the diseases may result in low disease incidence with a subsequent increase in yield and a reduction in production cost as less money is spent on disease control. In Asante Akim South and Offinso South where disease and pests management were not carried out, banana crops in the districts could suffer total crop failure from the two most deadly leaf diseases.

Rodents, birds and insects (banana weevils, white flies and ants) were common visitors on the farm. De Lapeyre and Mourichon (1997) pointed out that common visitors of the banana plant played an important role in the transmission of diseases and may also serve as vectors for primary inoculum. Legard *et al*. (1997) also added that proper field sanitation hindered disease development by reducing the amount of pathogenic inoculum present on the field. The presence of these rodents, birds and insects on the farms influence disease occurrence in the districts visited. These pests play an important role in disease transmission and occurrence and farmers may need to be educated on the importance of vectors in disease development.

5.1.4 Sucker and Bunch Management

De-suckering was practiced in six districts except for Sekyere South and Mampong Municipality. Regular de-suckering prevented competition between surplus suckers and the follower sucker, thus reducing the cycle time and enhancing overall yield. In order to retain the optimum plant population, it was very important to retain one follower sucker which in turn produces its own sucker. According to Nakasone and Paull, (1998) a good sucker selection and management system should have a maximum of three plants of different generations.

Bunch management involving the cutting off of the male inflorescence was practiced by the farmers in Sekyere South and Offinso South. De-budding reduced the amount of fungi spores present on the host. De Lapeyre and Mourichon (1997) identified the last bract leaf of the banana bunch and flower residues as major sources of crown rot inoculum. They further added that the flower remnants and the decaying last bunch bract were common inoculum sources for *Colletotrichum spp*. and *Fusarium spp*. Krauss and St. Rose (1996) also reported that deflowering at an early stage of bunch development reduces fungal inoculum.

In the other six districts; Asante Akim South, Asante Akim North Municipality, EjisuJuabeng Municipality, Sekyere East, Mampong Municipality and Kwabre East, where bunch management was not practiced, the male inflorescence and decaying flower remnants may serve as a major source of crown rot inoculum for bunch infection. The

farmers not de-budding the bunch in those districts may influence the incidence of crown rot disease. Hence, the best farm practices by farmers may reduce the amount of pathogenic spore concentration on the farm and, therefore, minimizes bunch contamination during fruit development.

5.1.5 Pre-Harvest Production Factors Influencing Crown Rot Disease Occurrence

Mulching with diseased leaves is one of the major factors influencing the incidence of crown rot disease in the districts under study. In Sekyere East, Sekyere South and Offinso South Municipality Districts, diseased banana leaves were used as mulch. These materials, may serve as a good substrate suitable for pathogenic fungi to sporulate for subsequent field infection. Some pathogenic fungi may require high inoculum levels for a successful bunch infection.

Another important factor in crown rot disease occurrence is bare soils. In Asante Akim South and Mampong Municipality Districts where the farms were not mulched, the bare soil may serve as a medium for spore survival when conditions are not favourable for sporulation to take place. According to De Lapeyre and Mourichon (1997) field infection is facilitated when rain splash hits the immediate soil surrounding the plant and transfer fungal inoculum unto hanging debris on the plant. No mulching may therefore influenced the incidence of the crown rot disease in the study area.

Pruning at the wrong time may also contribute significantly to the spread of the crown rot disease. In the eight districts under study, pruning was a common activity carried out during harvesting. The threat posed by this activity is where farmers prune and use the disease material as mulch material at the beginning of the rainy season may create a suitable environment for successful spore production and subsequent field infection. The correct practice by the farmers should be to prune regularly and diseased materials either by destroying by burying or by burning.

Lastly, the retention of the male inflorescence and dead bract on the bunch enhanced the incidence of the crown rot disease. In the six districts namely Asante Akim South, Asante Akim North Municipality, Ejisu-Juabeng Municipality, Sekyere East, Mampong Municipality and Kwabre East where de-budding of male inflorescence and destruction of flower remnants and decaying last bract were not done, it could be said that the level of inoculum on the field could be high and this may result in subsequent bunch infection. Studies done by De Lapeyre and Mourichon (1997) showed that the male inflorescence was a major source of crown rot inoculum for bunch contamination in the field. Proper bunch management practices such as de-budding at an early stage of bunch development and covering of bunch with polythene bags if practiced may help reduced fungal inoculum and the incidence of the crown rot disease.

5.1.6 Harvesting and Postharvest Operations

Bunches were usually harvested at the mature green stage determined through visual observation seen in the study area. Johnson (1988) noted that younger fruits were less susceptible to crown rot than older fruits of the same grade. Prusky (1996) concluded that harvesting at the mature green stage makes the fruits liable to latent infection from pathogenic fungi on the field since immature fruits contained enzymes that inhibited appressoria formation. *Colletotrichum musae* has been reported to establish a latent, subcuticular infection in the field during the early stages of the fruit development (Brown and Swinburne, 1980). Although latent infection contributes to crown rot, it is only relevant if it finds a window of opportunity in withering and senescing of the crown region (Krauss and Johanson, 2000). Thus in areas where proper field sanitation was not done, bunch contamination could be high and these could result in substantial fruit loss in storage as conditions become favourable for spore germination and growth.

The commonest harvesting tool used by the farmers was the machete. According to Kader *et al.* (1985), harvesting by hand remains the most predominant method for fruits intended for fresh produce market. Bunches were left in the open and sometimes under shades while awaiting transportation. Whole and dehanded bunches were sent directly to the market. In the five districts, Asante Akim South, Sekyere East and South, Kwabre East and Offinso South where bunches were dehanded before being transported to the market, the possibility of field contamination may have been high as Ploetz (2006) reported that field infection of banana fruits occurred primarily at the cut surface of the crown. The use of

dull knives during dehanding and trimming operation cause ragged edges and may favour entry of crown rot pathogens into adjacent sound tissues. However, the damage caused to the crown and pedicel tissues make the hand liable to spore contamination (Krauss and Johanson, 2000). Practices such as re-trimming of the crown believed to remove inoculum that might have invaded the outer layer of the crown tissue during exposure in the field after delatexing had been shown to reduce crown rot dramatically (Johnson, 1988).

5.1.7 Knowledge on Rot Diseases

The most common disease observed in storage was fruit rot. Fruits rots observed were dark brown to black in nature and mostly occurred at the tip of fruits, crown regions and in some cases as black spot spreading over the entire fruit length. Regular checking of the fruits and burying of rotten fruits were the control measures used in checking storage rot in six of the districts except for Mampong Municipality and Kwabre East where farmers did not have the knowledge to control the disease. Barkai-Golan (2001) reported that tropical and subtropical fruits were susceptible to storage rot diseases.

5.1.8 Constraints to Production

The banana industry in the region was faced with a lot of challenges ranging from inadequate funds for farm expansion, high cost of agricultural inputs, prevalence of Black Sigatoka disease, lack of market for harvest fruits to poor road network. Also, banana production in the districts received little attention compared with that given plantain because plantain is considered as an important staple food crop with wide consumption,

high potential for value addition and export and this has contributed to the shift in emphasis on the cultivation of banana to the cultivation of plantain (MoFA, 2002). The low priority given banana in terms of varietal development, general farm management practices, marketing constraint and the general lack of information on production systems and yield figures across the country poses a greater challenge to the expansion of the industry.

5.2 LABORATORY STUDIES

5.2.1 Isolation and Identification of Crown Rot Pathogens

Descriptions based on colony and spore characteristics of *Botryodiplodia theobromae, Colletotrichum gloeosporioides, Fusarium semitectum. Aspergillus flavus, Aspergillus niger and Aspergillus terreus* isolated from the eight districts were similar to those of Holliday (1995) and Mathur and Kongsdal (2003).

B. theobromae, *C. gloeosporioides* and *F. semitectum* were the primary fungi identified to be associated with crown rot disease in the eight districts visited. These pathogens were similar to what Johanson and Blasquez (1992) reported (i.e. *Colletotrichum spp., B. theobromae,* and *Fusarium spp.*) were the most common fungi isolated and responsible for causing crown rot disease. Okran (2005), working on banana samples collected from three locations in the Kumasi Metropolis, Ashanti Region isolated *C. musae, B. theobromae* and *F. moniliforme* var *subglutinans* as the pathogens associated with crown rot disease in Ghana.

A. flavus, A. niger and A. terreus on the other hand could not cause the disease when inoculated but could be saprophytes taking advantage of the opportunity created by the pathogens. Wallbridge (1981) reported that *Aspergillus spp*. were among pathogens frequently isolated from crown rots. According to Holliday (1995), *Aspergilus spp*. were common saprophytes inhabiting the soil and rhizosphere. In the tropics, they thrive well on decaying organic matter, stored grains and seeds and were also considered as frequent culture contaminants. These fungal species had been regarded as primary plant pathogens although they may often be associated with disease conditions. Typical examples are seen in *A. niger* which was found to cause black-mold rot in mango and *A. flavus* which also caused albinism in maize (Arauz, 2000).

5.2.2 Pathogenicity of Crown Rot Pathogens

In this study, the following fungal species *B. theobromae, C. gloeosporioides* and *F. semitectum*, thus were isolated from crown rot tissues in all the eight study districts.

These isolates were also shown in inoculation experiments to cause crown rot disease.

Johanson and Blasquez (1992) in their work reported *Colletotrichum spp., B. theobromae,* and *Fusarium spp.* as some of the organisms responsible for crown rot of banana. Okran (2005) also demonstrated and reported that organisms such as *C. musae*,

B. theobromae and *F. moniliforme* var *subglutinans* also caused crown rot when inoculed singly or in combination. The results of the study in Ashanti Region therefore confirm the reports of Okran (2005) and Johanson and Blasquez (1992). Amusa *et al*. (2003) confirmed

B. theobromae as the most destructive pathogen affecting the banana fruit. Ploetz (2003) reported that *F. semitectum* as one of the six species of *Fusarium* that caused crown rot in banana and therefore concluded that it was a primary wound pathogen that formed part of the crown rot disease complex. According to Marin *et al*. (1996), *F. semitectum* caused serious rot in Latin America, although in the present study it was not virulent in causing the disease.

Botryodiplodia theobromae being a wound pathogen causes both field and storage diseases in different crops because of its wide hosts ranging from fruits to plantation trees such as citrus, rubber, coffee, papaya, mango, cotton and sugar cane. *B. theobromae* is an important pathogen of mango causing stem end rot, soft rot of papaya guava and die-back disease in lemon plants (Alam and Nahar, 1990).

Colletotrichum gloeosporioides was known to be quiescence in nature and had a lot of host plants including avocado, papaya, banana, coffee and citrus. It is also reported to be responsible for anthracnose disease in mango where the fruit is produced under very humid conditions (Arauz, 2000).

Ploetz (2006) acknowledged that *Fusarium spp.* were significant plant pathogen with a diversity of hosts they affect. The fungus also attacks soybean bean (Roy and Ratnayake, 1997) and melon (Mc Govern, 1994).

Botryodiplodia theobromae inoculated singly caused severe rot followed by *Colletotrichum gloeosporioides* with *Fusarium semitectum* causing the least rot to inoculated crowns of banana. *B. theobromae* was therefore the most virulent of the three fungal pathogens causing crown rot in the study area visited. Postharvest losses resulting from rots caused by *B. theobromae* and *C. gloeosporioides* would be higher than that resulting from *F. semitectum.*

The extent of rotting following inoculation with the fungal organisms singly or in combinations differed significantly ($P<0.05$) from treatment to treatment. Anthony *et al*. (2004) in their study also indicated that in cases where combinations of virulent pathogens attack the fruit, the severity of the disease is often very high. Similar trend was observed combined inoculation of *B. theobromae* and *C. gloeosporioides* which recorded the longest rot length of 3.7cm. This result therefore, confirms the report of Anthony *et al*. (2004). Slabaugh and Grove (1982) also observed variations between the severity of the damage caused by the pathogens and the nature of the complex as was observed in the present study.

6.0 SUMMARY, CONCLUSIONS AND RECOMMENDATIONS

6.1 SUMMARY

A survey was undertaken to assess banana production and postharvest practices that might influence the occurrence of crown rot disease in eight districts which were identified to be the major banana production areas namely, Asante Akim South, Asante Akim North, Ejisu-Juabeng, Sekyere East, Sekyere South, Mampong, Kwabre East and Offinso South in the Ashanti Region of Ghana. Laboratory work to isolate and identify the causal organisms of crown rot disease in those identified areas in the region was carried out in the Pathology Section of the Laboratory of the Crops Research Institute, Fumesua.

The survey revealed that males dominated females in seven districts except for Asante Akim South where females dominated males in banana cultivation. Thirty-one percent of the farmers were in the age range of 40-49 years. Most of the farmers (60.7%) were semi-literate with basic education. Some of the farmers also engaged in extra economic activities such as petty trading, dress making, transportation, palm wine taping and agrochemical retailing. Majority of the farmers practiced mixed cropping with food crop (82.1%). Major staple food crops cultivated together with banana on the same piece of land included cassava, plantain, cocoyam, maize and vegetables crops. Cocoa, oil palm and citrus tree crops were also associated with intercropping farming systems where

banana was grown. Majority of the farmers (83.9%) cultivated the local banana variety "asante kwadu" and 67.3% of the farms acreages were between 1-5 acres of land. Banana suckers from ratoon crops were mostly used in farm establishment and were mostly obtained from ratoon crops from the farmer's own farm.

Cultural practices undertaken on the farm included weed control (98.2%), mulching (25%), pruning (62.5%) and diseases and pests control (23.2%). Weeding of the farm was done three times in a year (53.6%) in Asante Akim South, Ejisu-Juabeng Municipality, Mampong Municipality, Kwabre East and Offinso South Districts. Dry banana leaves were mostly used in mulching. Mulching was not practiced in Asante Akim South and Mampong Municipality Districts. Pruning was done to remove dead and diseased banana leaves. Pruning was done at harvest and pruned materials were used as mulch. Rodents, birds, banana weevils, white flies and ants were common pests seen on the field. The two most important diseases reported were Sigatoka and Fusarium wilt diseases. Pests and diseases were controlled as and when they occurred (70%).

De-suckering was practiced to remove excess suckers and to enhance plant growth. Farmers in Sekyere South and Mampong Municipality did not practice de-suckering operation. De-budding of the male inflorescence was also not practiced in Sekyere South and Offinso South. De-budding was done to reduce pests attack on fruits.

Majority of the farmers (96.2%) harvested the bunch in the unripe green stage. Maturity of fruit was determined through visual observation. Machete was the commonest tool used in harvesting. Harvested bunches were left in the open and under shade while waiting to be transported to the market. 82.7% of farmers conveyed whole bunch to the market.

Forty percent (40%) of farmers experienced rots in storage. Rots observed were described as dark brown to black in nature and were found mostly at the tip of fruits, crown regions and at times as spots on the finger. Regular checking of stored fruits
(50%) was the major control measure employed.

Major challenges affecting banana production identified included less attention given to the banana industry, inadequate funds for farm expansion, lack of market for harvested fruits, high cost of agricultural inputs, prevalence of Sigatoka disease and poor road network.

Botryodiplodia theobromae was frequently isolated from three districts; Asante Akim South, Asante Akim North and Offinso South. *Colletotrichum gloeosporioides* also dominated in Ejisu-Juabeng, Sekyere East and Sekyere South Districts. *Fusarium semitectum* was, however, frequently isolated from Mampong and Kwabre East Districts.

Botryodiplodia theobromae, *C. gloeosporioides* and *F. semitectum* were shown tp cause crown rot disease. *Aspergillus flavus*, *Aspergillus niger* and *Aspergillus terreus* on the other hand were found to be saprophytes that took advantage of the opportunity created by the primary infection.

Colletotrichum gloeosporioides, *B. theobromae* + *C. gloeosporioides* and *B. theobromae* + *C. gloeosporioides* + *F. semitectum* had 100% infection with a disease score of 4 in seven days after inoculation. *B. theobromae* + *C. gloeosporioides* recorded the longest rot length of 3.7cm in eight days after inoculation with *Botryodiplodia theobromae* recording the second longest rot length of 2.9cm in eight days.

6.2 CONCLUSIONS

Banana production practices in the eight districts studied were found to be similar. Mixed cropping system used was in association with other food crops such as cassava, plantain, cocoyam, maize and vegetable crops such as garden eggs, tomato, pepper and okra. The local variety of banana dominated production because of its adaptation to the local environment. The practice of using suckers from sources without proper cleaning facilitated the transfer of crown rot inoculum from one point to the other contributing to its wide distribution. Pre-harvest production practices such as mulching with diseased banana leaves served as a major inoculum source for more spore production, no mulching resulted in the exposure of the bare soil to direct rain drop impact facilitating spore dissemination. Pruning at the onset of the rains plays an important role in the incidence of

crown rot disease as the pruned materials were used as mulch facilitating abundant spore production and subsequent field infection. The retention of the male inflorescence was found to be a major source of inoculum for bunch contamination and this influenced the incidence of the disease in the banana producing areas.

The crown rot disease of banana occurred in all the eight districts studied. Three fungi, *Botryodiplodia theobromae, Colletotrichum gloeosporioides* and *Fusarium semitectum* were found to be responsible for the disease incidence. Their frequency of occurrence varied from location to location owing to the varying field conditions pertaining to a locality. *Botryodiplodia theobromae* was the most virulent of the three fungi followed by *C. gloeosporioides* and then *F. semitectum.* Pathogenicity test revealed that the rot caused by a combination of *B. theobromae* and *C. gloeosporioides* was far more devastating than crown rots caused by pathogens singly inoculated or in combination. The severity of the crown rot disease caused by individual fungi and a combination of them proved that several fungal pathogens are involved in the crown rot disease infection. Therefore, an effective crown rot disease control programme, in the studied districts must be based on the three fungal pathogens *B. theobromae, C. gloeosporioides* and *F. semitectum.* It is important that a similar study be carried out in the other months to identify other organisms that are common in that part of the year. This will help develop a more comprehensive control programme.

6.3 RECOMMENDATIONS

It is recommended that:

1. farmers should adopt modern pre-harvest practices (e.g. bunch covering, debudding etc.) aimed at reducing disease incidence on the banana fruit;
2. the Ministry of Food and Agriculture should intensify education of farmers on the use of appropriate production practices and adherence to good farm sanitation to reduce disease inoculum levels in the field and thereby minimize the incidence of crown rot disease in the field; and
3. farmers should use sharp and clean tools for both harvesting and dehanding operations to avoid damaging crown tissues as this enhances spore trapping and infection development.

REFERENCE

Anonymous (2001). Banana industry in distress [online]. Availabe from: http://www.modernghana.com/news/17172/1/banana-industry-in-distress.html. Accessed 17th October, 2008].

Adjei-Mensah, S. (2009). Interview with Eastern Regional secretary of GAWU [online]. Available from: http://www.bananalink.org.uk/ content/view/ 345/77/langen/. [Accessed 17th October, 2009].

Adu, S.V. (1992). *Soils of the Kumasi Region, Ashanti Region, Ghana*. Soil Research Institute, Kwadaso-Kumasi. p 141.

Agrios. G.N. (1988). *Plant Pathology*. 3rd ed. Academic Press Inc., San Diego, CA. p 803.

Alam, M.S. and Nahar. S. (1990). Post fungal infection changes in Lascorbic acid content of mango fruit. *Bangla Journal of Botany* **19**: 223-225.

Alvindia, D.G., Kobayashi, T., Yaguchi, Y. and Natsuaki, K.T. (2000). Symptoms and the associated fungi of postharvest diseases on non-chemical bananas imported from the Philippines. *Japanese Journal of Tropical Agriculture* **44**: 87-93.

Amusa, N. A., Ashaye, O. A., Oladepo, M. O. and Kafaru, O. O. (2003). Pre-harvest deterioration of Sour sop (*Annona muricata*) at Ibadan Southwestern Nigeria and its effect on nutrient composition. *African Journal of Bioctechnology* **2** (1): 23-25.

Anthony, S., Abeywickrama, K., Dayananda, R., Wijeratnam, S. and Arambewe, L. (2004). Fungal pathogens associated with bananas fruit in Sri Lanka, and their treatment with essential oils. *Mycopathologia* **157**: 91-97.

Arauz, L.F. (2000). Mango anthracnose: economic impact and current options for integrated management. *Plant Disease* **84** (6): 600-611.

Arias, P., Dankers, C., Liu, P. and Pilkauskas, P. (2003). The world banana economy 1985-2002 [online]. ESCR, FAO, Rome, Italy. Pp 100. Available from www.fao.org/docrep/007/y5102e/y5102e00.htm. [Accessed 6th May, 2007].

Arimoto, Y., Sugawara, F., Yoshida, S. and Yamaguchi, I. 1995. Prangolarin is a chemical facilitator for the enhanced development of the infection process in the epicarp *of Citrus limon* by *Penicillium digitatum. Journal of Agriculture and Food Chemistry* **43**: 2283-2285.

Baldry, J., Coursey, D.G. and Howard, G.E. (1981). The comparative consumers acceptability of triploid and tetreploid banana fruits. *Tropical Science* **23**: 33-66.

Banful, B. (1998). Production of plantain, an economic prospect for food security in Ghana. In: *Bananas and Food Security*. (C. Picq, E. Foure and E.A. Frison, eds). International symposium, 10-11 November, 1998, Douala, Cameroon. pp 151-160.

Barkai-Golan, R. (1990). Postharvest disease suppression by atmospheric modifications. In: *Food Preservation by Modified Atmospheres.* (M. Calderon and R. Barkai-Golan, eds.). CRC Press, Boca Raton, Fl. pp. 237-264.

Barkai-Golan, R. (2001). *Postharvest Diseases of Fruits and Vegetables: Development and Control.* Elsevier Science, Netherlands. p 431. ISBN: 0-444-50584-9.

Barkai-Golan, R. and Kopeliovitch. E. (1989). Effect of peel injury and enzymatic activity of the fruit on the tolerance of tomato genotypes to *Alternaria* infection. *Acta Horticulturae* **258**: 631-637.

Biederlack, L. and Rivers, J. (2009). Comprehensive food security and vulnerability analysis (CFSVA), Ghana. United Nations World Food Programme, Rome, Italy. P 168.

Brown, G.E. and Lee, H.S. (1993). Interactions of ethylene with citrus stem-end rot caused by *Diplodia natalensis. Phytopathology* **83**: 1204- 1208.

Brown, A.E. and Swinburne, T.R. (1980). The resistance of immature banana fruits to anthracnose (*Colletotrichum musae* (Berk. & Curt.) Arx). *Phytopathology Z.* **99**: 70-80.

Coates, L.M. and Johnson, G.I. (1992). Effective disease control in heat-disinfected fruit. *Postharvest News and Information* **4**: 35N-40N.

Coertze, S. and Holz, G. (1999). Surface colonization, penetration, and lesion formation on grapes inoculated fresh or after cold storage with single airborne conidia *of Botrytis cinerea. Plant Diseases* **83**: 917-924.

Combrink, J.C, Kotze, J.M., Wehner, F.C and Grobbelaar, CJ. (1985). Fungi associated with core rot of Starking apples in South Africa. *Phytophylactica* **17**: 81-83.

Dadzie, B.K. (1998). *Post-Harvest Characteristics of Black Sigatoka Resistant Banana, Cooking Banana and Plantian Hybrids.* INIBAP Technical Guidelines 4. International Plant Genetic Resources Institute, Rome, Italy. p 74.

Dadzie, B.K. (1999). *A Guide to Banana Production in Jamaica*. A Reference Manual. Natural Resource Institute. Chatham, UK. p 1.

Dadzie, B.K. and Orchard, J.E. (1997). *Routine Post Harvest Screening of Banana/Plantain Hybrids:Criteria and Methods.* INIBAP Technical Guidelines 2. International Plant Genetic Resources Institute, Rome, Italy; p 75. INIBAP ISBN: 2-910810-22-4.

De Langhe, E. (1995). Focus Paper 1: Banana and plantain; the earliest fruit crops? Annual Report. INIBAP, Montpellier, France. pp 6-8.

De Lapeyre de Bellaire, L. and Mourichon, X., (1997). The pattern of fungal contamination of the banana bunch during its development and potential influence on incidence of crown-rot and anthracnose disease. *Plant Pathology*. **46** : 481-489.

Dennis, C. (1983). Soft fruits. In: *Post-Harvest Pathology of Fruits and Vegetables*. (C. Dennis ed.). New York, Academic Press, pp. 23-42.

Dickman, M.B. and Alvarez, A.M. (1983). Latent infection of papaya caused by *Colletotrichum gloeosporioides. Plant Diseases* **67**: 748-750.

Eckert, J.W. (1990). Recent development in the chemical control of postharvest diseases. *Acta Horticulturae* **269**: 477-494.

Eckert, J.W. and Ogawa, J.M. (1988). The chemical control of postharvest diseases: deciduous fruits, berries, vegetables and root/tuber crops. *Annual Reviews of Phytopathology* **26**: 433-469.

Eden, M.A., Hill, R.A., Beresford, R. and Stewart, A. (1996). The influence of inoculum concentration, relative humidity, and temperature on infection of greenhouse tomatoes by *Botrytis cinerea. Plant Pathology* **45**: 798-806.

Edney, K.L. 1983. Top fruit. In: *Post-Harvest Pathology of Fruits and Vegetables*. (C. Dennis, ed.). Academic Press, London, pp. 43-71.

FAO, (2001). Contribution of bananas to income, employment and food security in Ghana and Ecuador; Committee on commodity problems [online]. Intergovernmental group on bananas and on tropical fruits. San José, Costa Rica. Available from: www.fao.org/DOCREP/MEETING/004/Y1871e.HTM. [Accessed 6th May, 2007].

FAO, (2004). Assessment of food import and food aid against support for agricultural development: The case of Ghana. A draft report for the Food and Agriculture Organization Regional Office, Accra, Ghana. p 55.

Finlay, A. R. and Brown, A. E. (1993). The relative importance of *Colletotrichum musae* as a crown-rot pathogen on Windward Island bananas. *Plant Pathology* **42** (1): 67-74

Finlay, A.R., Lubin, C. and Brown, A.E. (1992). The banana stalk as a source of inoculum of fungal pathogens which cause crown rot. *Tropical Science* **32**: 343– 352.

Fitzell, R.D. and Peak, CM. (1984). The epidemiology of anthracnose disease of mango: inoculum sources, spore production and dispersal. *Annals of Applied Biology* **104**: 53-59.

Flaishman, M.A. and Kolattukudy, P.E. (1994). Timing of fungal invasion using host's ripening hormone as a signal. *Proceedings of National Academy of Science*, USA **91**: 6579-6583.

Fourie, J.F. and Holz, G. (1998). Effect of fruit and pollen exudates on growth of *Botrytis cinerea* and infection of plum and nectarine fruit. *Plant Disease* **82**: 165170.

Frison, E.A., Gold, C.S. Karamura, E.B. and Sikora, R.A. (1998). Mobilizing IPM for sustainable banana production in Africa. Proceedings of a workshop on banana IPM, November, 1998, Nelspruit, South Africa. INIBAP. p 341.

Fuchs, Y., Barkai-Golan, R., Aharoni, N. and Rot, I. (1984). Keeping quality of tomato fruit as affected by harvest methods and transport conditions. *Acta Horticulturae* **163**: 121-123.

GEPC, (2006). Ghana Export Promotion Council Annual Report. Accra, Ghana.

Gowen, S. (1995). *Banana and Plantain*. Chapman and Hall, London, UK. Pp 337-417.

Holliday, P. (1995). *Fungus Diseases of tropical Crops*. Dover Publication, New York. p 607. ISBN 0-486-. 68647-7.

Hong, E.X., Michailides, T.J and Holtz, B.A. (1998). Effects of wounding, inoculum density and biological control agents on postharvest brown rot of stone fruits. *Plant Diseases* **82**: 1210-1216.

IITA, (1992). Sustainable food production in Sub-Saharan Africa. International Institute of Tropical Agriculture, Ibadan, Nigeria. Pp 208.

Johanson, A., (1988). Report on a visit to WINBAN research and development division, St. Lucia, 18 August–12 November, 1988. ODNRI Project No. A1967.

Johanson, A. and Blasquez, B. (1992). Fungi associated with banana crown-rot on fieldpacked fruit from the Windward Islands and assessment of their sensitivity to the fungicides thiabendazole, prochloraz and imazalil. *Crop Protection* **11**: 79-83.

Johnson, G.I., Highley, E. and Joyce D.C. (1998). Diesease resistance in fruits. Australian Centre for International Agricultural Research (ACIAR) proceedings. p 233.

Kader, A.A., Kasmire, R.F., Mitchell, F.G., Reid, M.S., Sommer, N.F. and Thompson, J.F. (1985). *Postharvest Technology of Horticultural Crops*. University of California Special Publication No. 3311. p192.

Karamura, E.B (1992). Banana/Plantain production constraints as a basis for selecting research priorities. In: Proceedings of the Regional Advisory Committee Meeting, 23-25 September 1991, Kampala Uganda. INIBAP. P

Karamura, E.B. (1993). The strategic importance of bananas/plantains in Uganda. In: *Biological and Integrated Control of Highland Banana and Plantain Pests and Diseases*. In: Proceedings of a Research Coordination Meeting, 12-14 November 1991, Cotonou, Benin (C.S. Gold & B. Gemmill, eds.). IITA, Ibadan, Nigeria. pp. 384-387.

Katan, J. (1987). Soil solarization. In: *Innovative Approaches to Plant Disease Control*. (I. Chet, ed.). John Wiley & Sons, New York. pp. 77-105

Kena, K. 1996. Soil problems associated with enset production. In: *Enset-based sustainable Agriculture in Ethiopia* (T. Abate, C. Hiebsch, S.A. Brandt and S. Gebremariam, eds.). Institute of Agricultural Research, Addis Abeba, Ethiopia. pp. 271-275

KMA, (2007). Fact Sheets on Ashanti Region. Draft report submitted to the Regional Co-ordinating Council. Kumasi Metropolitan Assembly, Kumasi, Ghana. p 25.

Knight, C., Cutts, D.F. and Colhoun, J. (1977) The role of *Fusarium semitectum* in causing crown rot of bananas. *Phytopathology Zeits* **89**: 170-176.

Krauss, U. and Johanson, A. (2000). Recent advances in the control of crown rot of banana in the Windward Islands [online]. *Crop Protection* **19** (3): 151-160. Available from: http://www.aginternetwork.net/whalecomwww.aginternetwork.org/whalecom0/en/journals/decodeDOI.do?doi=10.1016/S0261-2194(99)00097-6. Accessed 10th March, 2008].

Krauss, U. and St. Rose, M. (1996). Improved crown rot control in the field and in the shed. Fact Sheet No.1, WIBDECO Technical Services Division, St. Lucia.

Lassois, L., de Lapeyre de Bellaire, L. and Jijakli, M.H. (2008). Biological control of bananas with *Pichia anomala* strain K and *Candida oleophila* strain O [online]. *Biological Control* **45**: 410-418. Available from: http://www.aginternetwork.net/whalecomwww.aginternetwork.org/whalecom0/en/journals/journalhome.do?issn=1049-9644&recId=. [Accessed 8th August, 2008].

Lavy-Meir, G., Barkai-Golan, R. and Kopeliovitch, E. (1989). Resistance of tomato ripening mutants and their hybrids to *Botrytis cinerea*. *Plant Diseases* **73**: 976-978.

Legard, D.E., Bartz, I.A., and Chandler, (1997). The control of strawberry diseases by sanitation. International Strawberry Symposium 3. *Acta Horticulturae* **439**: 917922.

Marin, D.H., Sutton, T.B. and Barker, K.R. (1996). Dissemination of Bananas in Latin America and the Carribbean and its relationship to the occurrence of Radopholus similis. *Plant Diseases* **82** (9): 964-974.

Marin, D.H., Sutton, T.B., Blankenship, S.M. and Swallow, W.H. (1996). Pathogenicity of fungi associated with crown rot of bananas in Latin America on Grande Naine and disease-resistant hybrid bananas. *Plant Diseases* **80**: 525-528.

Mathur, S. B. and Konsdal, O. (2003). Common Laboratory Seed Health Testing Methods for detecting fungi. Basserdorf, Swizterland: ISTA. p 425.

Mc Govern, R.J. (1994). First report of corky dry rot of cantaloupe caused by *Fusarium semitectum* in Florida. *Plant Diseases* **78**: 926.

MoFA, (2002). Food and agriculture sector development policy (FASDEP I). Ministry of Food and Agriculture, Accra, Ghana. p 66.

MoFA, (2006). Agriculture in Ghana: Facts and Figures. Draft Report, Ministry of Food and Agriculture, Accra, Ghana. p 55.

Mourichon, X., Carlier, J. and Fouré, E. (1997). Sigatoka leaf spot diseases. Musa Disease Fact Sheet No. 8. International Network for the Improvement of Banana and Plantain (INIBAP), Montpellier France. p 4.

Muirhead, I.F. (1981). The role of appressorial dormacy in latent infections. In:

Microbial Ecology of the Phylloplane. (J. P. Blakeman, ed.). Academic Press, London, pp. 155-167.

Muirhead, I.F. and Deverall, B.J. (1981). Role of appressoria in latent infection of bananas by *Colletotrichum musae*. *Physiological Plant Pathology* **19**: 77-84.

Nakasone, H.Y. and Paull, R.E. (1998). *Tropical Fruits: Production Science*. Horticulture (7). CAB International. Wallingford, UK. Pp 127-130.

Nishijima, W.T., Ebersole, S. and Fernandez, J.A. (1990). Factors influencing development of postharvest incidence of Rhizopus soft rot of papaya. *Acta Horticulturae* **269**: 495-502.

Okran, J. K. (2005). Effects of postharvest hot water and fungicide application on the severity of crown rot disease and quality of Cavendish bananas (Musa spp.). Unpublished MSc. Thesis submitted to Kwame Nkrumah University of Science and Technology, Kumasi, Ghana.

Palti, J. (1981). *Cultural Practices and Infectious Crop Diseases*. Springer-Verlag, Heidelberg, p 243.

Paull, R.E., Gross, K. and Qiu, Y. (1999). Changes in papaya cell walls during fruit ripening. *Postharvest Biology and Technology* **16**: 79-89.

Picq, C., Foure, E. and Frison, E.A. (1998). Bananas and food security. International symposium, Douala, Cameroon, 10-11 November, 1998. INIBAP. pp 30-31.

Ploetz, R.C. (2003). *Diseases of Tropical Fruit Crops*. CABI Publishing, Wallingford, UK. p 544.

Ploetz, R.C. (2006). *Fusarium*-induced diseases of tropical, perennial crops. *Phytopathology* **96**: 648-652.

Ploetz, R.C., Zentmyere, G.A., Nishijima, W.T., Rohrbach, K.G. and Ohr, H.D. (1994). *Compendium of Tropical Fruit Diseases*. APS Press, St. Paul, MN, p 88.

Prusky, D. (1996). Pathogen quiescence in postharvest diseases. *Annual Reviews of Phytopathology* **34**: 413-434.

Prusky, D. and Keen, N.T. (1993). Involvement of preformed antifungal compounds in the resistance of subtropical fruits to fungal decay. *Plant Diseases* **72**: 114-119.

Prusky, D., Ben-Arie, R. and Guelfat-Reich, S. (1981). Etiology and histology of Alternaria rot of persimmon fruits. *Phytopathology* **71**: 1124-1128.

Prusky, D., Fuchs, Y. and Yanko, U. (1983). Assessment of latent infections as a basis for control of postharvest disease of mango. *Plant Diseases*. **67**: 816-818.

Prusky, D., Kami, L., Kobiler, I. and Plumbley, R.A. (1990). Induction of the antifungal diene in unripe avocado fruits: effect of inoculation with *Colletotrichum gloeosporioides. Physiology of Molecular Plant Pathology* **37**: 425-435.

Ranasinghe, L., Jayawardena, B. and Abeywickrama, K. (2002). Fungicidal activity of essential oils of *Cinnamomum zeylanicum* (L) and *Syzygium aromaticum* (L) Merr et L.M. Perry against crown rot and anthracnose pathogen isolated from banana. *Letters in Applied Microbiology* **35**: 208-211.

Roy, K.W. And Ratnayake, S. (1997) Frequency of occurence of *Fusarium pallidoroseum*, effects on seed and seedlings, and associations with other fungi in soyabean seeds and pods. *Candian Journal of Plant Pathology* **19**: 188-192.

Samson, J.A. (1980). *Tropical Fruits*. Longman, London. p 119-163.

Sarananda, K.H. and Wijeratnam, R.S.W. (1994). Controlled atmosphere storage of Embul bananas. *Tropical Agricultural Research* **6**: 17-22.

Sastry, P.S.N., (1988). *Agrometeorology of the Banana Crop*. Agricultural Meteorology, CAgM Report 29, World Meteorological Organization, Geneva. p 95.

Schoofs, H., Panis, B., Strosse, H., Mosqueda, A.M., Torres, J.L., Roux, N. Dolezel, J. and Swennen, R. (1999). Bottlenecks in the generation and maintenance of morphologenic banana cell suspensions and plant regeneration via somatic embryogenesis therefrom. *INFOMUSA* **8**(2): 3-6.

Sepiah, M. and Nik Mohd, N. A. M. (1987). Effects of benomyl and prochloraz on post-harvest diseases of banana. *ASEAN Food Journal* **3**:101-104.

Sharpies, R.O. (1984). The influence of pre-harvest conditions on the quality of stored fruit. *Acta Horticulturae* **157**: 93-104.

Sinclair, J.B. (1991). Latent infection of soybean plants and seeds by fungi. *Plant Diseases* **75**: 220-224.

Slabaugh, W.R. and Grove, M.D. (1982). Postharvest diseases of bananas and their control. *Plant Diseases* **66**: 746-750.

Snowdon, A.L. (1990). *Post-Harvest Diseases and Disorders of Fruits and Vegetables Vol. 1: General Introduction and Fruits.* CRC Press, Inc., Boca Raton, p 302.

Snowdon, A.L. (1992). *Post-Harvest Diseases and Disorders of Fruits and Vegetables, Vol. 2: Vegetables*. CRC Press, Inc., Boca Raton. p 416.

Sommer, N.F. (1985). Role of controlled environments in suppression of postharvest diseases. *Canadian Journal of Plant Pathology* **7**: 331-339.

Spalding, D.H. and Reeder, W.F. (1986). Decay and acceptability of mangos treated with combinations of hot water, imazalil, and gamma-radiation. *Plant Diseases* **70**: 1149-1151.

Speijer, P.R., Kajumba, Ch. and Tushemereirwe, W.K. (1999). Dissemination and adaptation of a banana clean planting material technology in Uganda. *INFOMUSA* **8**(2): 11-13.

Spotts, R.A., Holmes, R.J. and Washington, W.S. (1988). Factors affecting wet core rot of apples. *Australian Plant Pathology* **17**: 53-57.

Stover, R.H. (1986). Disease management strategies and the survival of the banana industry [online]. *Annual Reviews of Phytopathology* **24**: 83-91. Available from: http://arjournals.annualreviews.org/doi/pdf/10.1146/annurev.py.24.090186.000503. [Accessed 12th July, 2008].

Stover, R. H. and Simmond, N. W. (1987). *Bananas* (3rd edition). John Wiley and Sons, Inc. New York. p468.

Swennen, R. (1990). *Plantain cultivation under West African conditions. A reference manual*. International Institute for Tropical Agriculture, Ibadan, Nigeria. Amarin Printing Group Co. Ltd. Thailand. p 24.

Thangavelu, R., Sangeetha, G. and Mustaffa, M. M. (2007). Cross-infection potential of crown rot pathogen (*Lasiodiplodia theobromae*) isolates and their management using potential native bioagents in banana. *Australasian Plant Pathology* **36**(6) 595–605.

Wainwright, H. (1992). Improving the utilization of cooking bananas and plantains.

Outlook on Agriculture **21**: 177-181.

Wallbridge, A. (1981). Fungi associated with crown-rot disease of boxed bananas from the Windward Islands during a two year survey. *Transactions of the British Mycological Society* **77**: 567-577.

Win, N.K.K., Jitareerat, P., Kanlayanarat, S. and Sangchote, S. (2007). Effects of cinnamon extract, chitosan coating, hot water treatment and their combination on crown rot disease and quality of banana fruits. *Postharvest Biology and Technology* **45** (3): 333-340.

APPENDICES

APPENDIX A: FREQUENCY TABLES FOR THE FIELD SURVEY

Appendix A1: Sex of respondents

District/ Municipality	Male	Female	Total
Asante Akim South	42.9	57.1	100
Asante Akim North	85.7	14.3	100
Ejisu-Juabeng	57.1	42.9	100
Sekyere East	85.7	14.3	100
Sekyere South	57.1	42.9	100
Mampong	100	0	100
Kwabre East	71.4	28.6	100
Offinso South	71.4	28.6	100
Total	**71.4**	**28.6**	**100**

Appendix A2: Educational level of respondents

District/ Municipality	No formal education	Basic education	Secondary	Tertiary	Total
Asante Akim South	14.3	57.1	14.3	14.3	100
Asante Akim North	42.9	57.1	-	-	100

Ejisu-Juabeng	14.3	71.4	14.3	-	100
Sekyere East	14.3	71.4	-	14.3	100
Sekyere South	28.6	57.1	-	14.3	100
Mampong	28.6	57.1	-	14.3	100
Kwabre East	28.6	57.1	-	14.3	100
Offinso South	14.3	57.2	28.6	-	100.1
Total	**23.2**	**60.7**	**7.1**	**8.9**	

Appendix A3: Sources of planting material used in farm establishment

District/ Municipality	**Own farm**	**Family farm**	**Friends farm**	**Market**	**Total**
Asante Akim South	66.7	-	33.3	-	100
Asante Akim North	66.7	16.7	16.7	-	100
Ejisu-Juabeng	100	-	0	-	100
Sekyere East	30	30	30	10	100
Sekyere South	57.1	-	42.9	-	100
Mampong	100	-	0	-	100
Kwabre East	85.7	-	14.3	-	100
Offinso South	20	-	80	-	100
Total	**64.2**	**7.5**	**26.4**	**1.9**	**100**

Appendix A4: Cultural practices carried out on farm

District/ Municipality	Weeding	Mulching	Pruning	Disease and pests control
Asante Akim South	Yes	No	Yes	No
Asante Akim North	Yes	Yes	Yes	Yes
Ejisu-Juabeng	Yes	Yes	Yes	Yes
Sekyere East	Yes	Yes	Yes	Yes
Sekyere South	Yes	Yes	Yes	Yes
Mampong	Yes	No	Yes	Yes
Kwabre East	Yes	Yes	Yes	No
Offinso South	Yes	Yes	Yes	Yes

Appendix A5: Occurrence of fruit rots in storage

District/ Municipality	Fruit rot	No fruit rot	Total
Asante Akim South	57.1	42.9	100
Asante Akim North	42.9	57.1	100
Ejisu-Juabeng	71.4	28.6	100
Sekyere East	14.3	85.7	100
Sekyere South	57.1	42.9	100
Mampong	-	100	100
Kwabre East	42.9	57.1	100
Offinso South	26.8	71.4	100
Total	**40**	**60**	**100**

APPENDIX B: ANALYSIS OF VARIANCE (ANOVA) TABLES

Appendix B1: ANOVA Table for Disease Score (Day 3)

Source	DF	SS	MS	F	P
Treatment	7	2.95833	0.42262	3.38	0.0207
Error	16	2.00000	0.12500		
Total	23	4.95833			

Grand Mean 0.7083 CV 49.91

Appendix B2: ANOVA Table for Disease Score (Day 4)

Source	DF	SS	MS	F	P
Treatment	7	7.29167	1.04167	6.25	0.0012
Error	16	2.66667	0.16667		
Total	23	9.95833			

Grand Mean 1.2083 CV 33.79

Appendix B3: ANOVA Table for Disease Score (Day 5)

Source	DF	SS	MS	F	P
Treatment	7	3.83333	0.54762	3.29	0.0231
Error	16	2.66667	0.16667		
Total	23	6.50000			

Grand Mean 1.7500 CV 23.33

Appendix B4: ANOVA Table for Disease Score (Day 6)

Source	DF	SS	MS	F	P
Treatment	7	9.3333	1.33333	8.00	0.0003
Error	16	2.6667	0.16667		
Total	23	12.0000			

Grand Mean 2.5000 CV 16.33

Appendix B5: ANOVA Table for Disease Score (Day 7)

Source	DF	SS	MS	F	P
Treatment	7	16.6667	2.38095	5.71	0.0019
Error	16	6.6667	0.41667		
Total	23	23.3333			

Grand Mean 3.3333		CV 19.36			

Appendix B6: ANOVA Table for Disease Score (Day 8)

Source	DF	SS	MS	F	P
Treatment	7	9.2917	1.32738	7.96	0.0003
Error	16	2.6667	0.16667		
Total	23	11.9583			
Grand Mean 3.5417		CV 11.53			

Appendix B7: ANOVA Table for Mean rot length (Day 8)

Source	DF	SS	MS	F	P
Treatment	7	25.0463	3.57804	5.07	0.0035
Error	16	11.2933	0.70583		
Total	23	36.3396			
Grand Mean 2.1042		CV 39.93			

APPENDIX C: SAMPLE QUESTIONNAIRE ADMINISTERED TO FARMERS

Kwame Nkrumah University of Science and Technology, Kumasi
Department of Horticulture

This questionnaire was designed to evaluate the production practices undertaken in major banana producing areas in the Ashanti Region.

All information provided will be treated as confidential as possible. Please be as objective and brief as possible.

District: ……..
Location of farm: ……

BIODATA

1. Sex of respondent a. Male [ ] b. Female [ ]
2. Age of respondent a. 20-29 yrs [ ] b. 30-39 yrs [ ] c. 40-49 yrs [ ]
   d. 50-59 yrs [ ] d. 60 years and above [ ]
3. Educational background a. No formal education [ ] b. Basic education [ ]
   c. Secondary education [ ] d. Tertiary education [ ]
4. Do you engage in any other activity apart from farming? a. Yes [ ] b. No [ ]
5. If yes, what other activity do you engage in? ……..……

PRODUCTION PRACTICES

6. What system of farming do you practice? a. Mono-cropping [ ]
   b. Mixed cropping with food crop [ ] c. Intercropping with tree crop [ ]
7. What other crop(s) do you cultivate in addition to banana?
   ……..……
8. What varieties of banana do you cultivate?
   a. Local variety [ ] b. Improved variety [ ]
9. What is the acreage of your farm? ……..
10. What planting material do you use in farm establishment? a. Suckers [ ]
    b. Plantlets [ ] c. Others [ ], specify ……
11. What is the source of your planting material? a. Own farm [ ] b. Family farm [ ]
    c. Friend's farm [ ] d. Research stations [ ] e. Market [ ]
12. Do you clean suckers before planting? a. Yes [ ] b. No [ ]

CULTURAL PRACTICES

13. Which of the following cultural activities do you carry out on your farm?

    a. Weed control [ ]

    b. Mulching [ ]

    c. Pruning [ ]

    d. Disease and pests control [ ]

If you answered '**yes**' to **question 13 a, b, c** or **d** above then answer **questions 14 to 20**.

14. How often do you control weeds in a growing season? a. Once [ ] b. Twice [ ] c. Thrice [ ] d. Four times [ ] e. Others [ ], specify ……..

15. What material do you use in mulching? ……..

16. What material do you prune? a. Dead leaves [ ] b. Diseased leaves [ ] c. Others [ ], specify ……....

17. Why do you prune? ……...……
……..……..……

18. How often do you prune? ……..…

19. What type of pests and diseases do you observed on your farm? …….
……..……...

20. How often do you control pests and diseases on your farm?

    a. Routine spraying with agro-chemicals [ ] b. As and when necessary [ ]

SUCKER AND BUNCH MANAGEMENT

21. Do you practice de-suckering? a. Yes [ ] b. No [ ]

22. If yes, why do you control sucker growth?.....

23. Do you practice de-budding of male inflorescence? a. Yes [ ] b. No [ ]

24. If yes, why do you de-bud the male flower? ……

HARVESTING AND POSTHARVEST HANDLING OPERATIONS

25. At what stage do you usually harvest your fruit? a. Unripe [ ] b. Ripe [ ]

26. How do you determine the stage of maturity of the fruit?

    a. Visual observation [ ] b. Calendar date [ ]

27. What tool do you use in harvesting the fruit? ….……..…….

28. How do you convey the harvested fruits from the farm?

    a. Whole bunch [ ] b. Dehanded bunch [ ]

29. Do you carry out any treatment(s) on the harvested fruits? a. Yes [ ] b. No [ ]

30. If yes, why? ……...……

KNOWLEDGE ON STORAGE ROT DISEASES

31. Do you experience rots in storage? a. Yes [ ] b. No [ ]

32. If yes, how is the rot like? Describe ……..…

    .....

33. How do you control the rot disease? ……..…

    ……

34. What other constraints affect your banana production? ……

    .....

35. General Comments ……

    .....

    .....

    .....

THANK YOU!