

## CHAPTER ONE

### INTRODUCTION

Yams (*Dioscorea* spp.) are among the most important staple foods in the world, especially some parts of the tropics and subtropics (Okigbo and Ogbonnaya, 2006). The role played by yam in the food economy in most West African countries cannot be over-emphasised. It is one of the most important dietary sources of energy produced within the tropics. Significantly, yam contributes to food security in Ghana and its availability on the market for a considerable part of the year helps prevent food shortages, particularly in the urban communities because it stores relatively longer than other root crops. The income generated by rural poor farmers who are engaged in yam production improves their living standards. Stored yam represents stored wealth which can be sold all-year-round by the farmer or marketer.

In 2005, FAO reported that Nigeria produces about 66.6% (26.6 million metric tonnes) of total world's yam production, with Ghana producing 9.8% (3.9 million metric tonnes) every year. Ghana produces yams for local consumption and the export market. The country is a leading exporter of yam in the world (export of about 12,000 tonnes annually). In Ghana, yam is produced mostly in the Guinea-Savanna and Forest-Savanna transition zones. However, reasonable production occurs in almost all regions. White yam (*D. rotundata*) is much preferred to the other yam varieties and it constitutes about 80% of total yam produced in Ghana (Tetteh and Saakwa, 1994). Water yams (*D. alata*) are consumed when white yam becomes scarce or expensive.

There are several constraints to the yam industry in the country. Of these constraints, diseases contribute greatly to high yield losses before and after harvest. Yam plants are

prone to infection by fungi, bacteria, and viruses at all stages of growth and also during storage of tubers.

Rot is a major factor limiting the post-harvest life of yams and losses can be very high. Losses due to post-harvest rot significantly affect farmers' and traders' income, food security and seed yams stored for planting. The quality of yam tubers are affected by rots, which makes them unappealing to consumers. In Nigeria, over 60% of white yam varieties get rotten when stored for less than six months (Adesiyan and Odihirin, 1975). Similar situations or worse can be found in Ghana. Though figures are not available, observations from farmers' fields and discussions reveal that some farmers lose as high as 70% of their stored yam to rot organisms. Some white yam varieties such as 'dente', 'pona' and 'labreko', that are preferred by most consumers in Ghana, do not store for a long time due to attack by rot organisms. Because of their poor storability, farmers sell produce just after harvest to avoid losses, and this result in low income or reduced profits. This practice also affects farmers' food security particularly in the lean season.

Most rots of yam tubers are caused by pathogenic fungi such as *Aspergillus flavus*, *Aspergillus niger*, *Botryodiplodia theobromae*, *Fusarium oxysporum*, *Fusarium solani*, *Penicillium chrysogenum*, *Rhizoctonia* spp., *Penicillium oxalicum*, *Trichoderma viride* and *Rhizopus nodosus* (Okigbo and Ikediugwu, 2002; Okigbo, 2004; Aidoo, 2007).

The storage methods for yam in most farming communities in Ghana are very poor. Yams are normally stored either in dug pits, in barns or by gradual harvesting. These storage systems are prone to infections by soil-borne microorganisms (especially pathogenic fungi) that are likely to cause rot infections when storage is prolonged.

This work was done with the primary aim of improving farmers' indigenous storage practices that are cost effective and could easily be practiced to increase on-farm storage life of some white yam varieties. In addition, the primary organisms that are associated with rots of white yam tubers and their pathogenicity were studied.

The specific objectives were to:

- 1 To document farmers' knowledge on field and post-harvest diseases of yam.
- 2 To establish the pathogenicity of fungal organisms associated with tuber rots of white yam varieties.
- 3 To study the effectiveness of some chemical fungicides in reducing yam tuber rot in storage.
- 4 To study the effectiveness of some botanical extracts in controlling yam tuber rot fungi.



Figure 1: Yam tuber ('pona') showing symptoms of a tuber rot disease.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1 DESCRIPTION OF YAM:

Yam is the common name for members of the genus *Dioscorea* (family *Dioscoreaceae*). It is probably one of the oldest food crops known to man. The word 'yam' comes from Portuguese *inhame* or Spanish *ñame*, which both ultimately derive from the Wolof word *nyame*, meaning 'to eat'. Yams are native to tropical regions throughout the world. They are cultivated for their edible tubers, which in some species can grow up to about 2.4m long and with weight up to 45kg. The inconspicuous white or greenish-yellow flowers of yams, arranged in spikes or racemes, have a six-parted calyx (outer flower whorl), a six-lobed corolla (inner floral whorl), six stamens, and a solitary pistil. The fruit of the yam consists of a membranaceous, three-winged capsule (Encarta, 2006).

There are more than six hundred (600) species of yam (Kay, 1987). Some of the cultivated species are *Dioscorea rotundata* (White yam), *D. dumetorum* (Bitter yam), *D. cayensis* (Yellow yam), *D. alata* (Water yam), *D. esculenta* (Chinese yam) and *D. bulbifera* (Aerial yam).

#### 2.2 IMPORTANCE OF YAM:

Yams are one of the most highly regarded food products in tropical countries of West Africa and are closely integrated into social, economic, cultural and religious aspects of communities (Okigbo and Ogbonnaya, 2006). The ritual ceremony and superstition often

surrounding yam and its utilization in West Africa is a strong indication of the antiquity of use of this crop (Norman *et al.*, 1995). Aside their high values as a food source, some species of yam have been used medicinally to treat diseases like diabetes mellitus, coronary disorders and in preventing high hypercholesterolemia (Undie and Akubue, 1986). Yam starch takes longer time to break down compared with other starchy tubers like potato and sweet potato, which makes it a safer source of carbohydrate for diabetics. It is a good source of manganese, a vital micronutrient.

Some yam species such as *D. piscatorum* have toxic properties that allow them to be used in the production of insecticides. An insecticide from *D. piscatorum* is used in controlling insect pests of rice in Malaysia. Extracts from *D. deltoidea* is used in the production of anti-lice shampoo in India (Coursey, 1967).

### **2.3 YAM PRODUCTION AND CONSUMPTION:**

The yam tuber is an organ that is considered either easy or difficult to store. In the former case, its role in the food supply of sailors at the time of the caravels and for Oceanians during their migrations across the Pacific is stressed. In the latter, records indicate that nearly 50% of all kinds of yam stocks was often lost after six months, particularly in Africa (Coursey, 1967).

Yam is a valuable source of carbohydrate to the people of the tropical and subtropical Africa, Central and Southern America, parts of Asia, the Caribbean and Pacific Islands (Coursey, 1967). Out of the World production of over 30 million tonnes per annum, Nigeria alone produces 22 million tones (FAO, 1998). In Ghana, daily consumption is estimated at 0.5 – 1.0 kg per person (Purseglove, 1989). In Ghana, major areas of

commercial yam production include Ejura, Mampong, Wenchi, Kintampo, Atebubu, Yendi, Tamale, Bole, Wa and Kete-Krachi (Twumasi, 1986).

#### **2.4 NUTRITIONAL VALUE OF YAM:**

Yam shows nutritional superiority over other tropical root and tuber crops. Yams are the most nourishing plants in the diet of many inhabitants of inter-tropical region. The nutritional value of yam confirms its importance to mankind. It is a major source of carbohydrate, minerals of calcium, phosphorus, iron and vitamins such as riboflavin, thiamin and vitamins B and C (Coursey, 1967). Yam is largely carbohydrate and is one of the cheaper sources of carbohydrate to man (Kochlar, 1981).

#### **2.5 ECONOMIC IMPORTANCE OF ROT:**

Post-harvest losses account for a reduction of about 26% in world yam production (Coursey and Booth, 1972). Booth (1974) estimated annual post-harvest yam loss in West Africa to be as high as 5 million tonnes. Adesiyun and Odihirin (1975) reported that post harvest losses of tubers could be as high as 80% in storage. Ikotun (1989) reported that 25% of post-harvest losses of yam in storage are due to diseases. Losses due to rots affect availability, food security and revenue of farmers and traders. To reduce post-harvest losses and increase yam availability between harvests and avoid large fluctuations in supply and, therefore price, good storage is required. Good storage should maintain tubers in their most edible and marketable conditions by preventing large moisture losses and spoilage by pathogens (Osagie, 1992; Amusa *et al.*, 2003).

## 2.6 INITIATION OF ROT:

Rots of fleshy parts of plants develop as tissues are disintegrated by the action of microorganisms. Extra cellular enzymes are produced in advance of the bacterial cells or fungal hyphae of the attacking pathogens. The affected tubers become hydrotic and soft, turn brown, emit offensive odour and exhibits a sharp demarcation between a healthy intact tissue and a diseased tissue.

## 2.7 CAUSAL AGENTS OF YAM ROT:

Yams are subject to several diseases caused by viruses, bacteria and fungi. Fungi, however, are the major causes of post harvest rots of yam tubers (Noon, 1978; Okigbo and Ikediugwu, 2000; Coursey, 1967). The major microorganisms causing rot diseases in yams include *Aspergillus flavus* Lark ex Fr., *Aspergillus niger* Van Tiegh, *Botryodiplodia theobromae* Pat, *Fusarium oxysporum* Schecht ex Fr., *Fusarium solani* (Mart.) Sacc., *Penicillium chrysogenum* Thom, *Rhizoctonia* spp., *Penicillium oxalicum* Currie and Thom, *Trichoderma viride* Pers. ex S.F. Gray and *Rhizopus nodosus* N'amyslowski (Okigbo and Ikediugwu, 2002).

Nine fungal species including *Aspergillus flavus*, *Aspergillus niger*, *Botryodiplodia theobromae*, *Fusarium culmorum*, *Fusarium oxysporum*, *Fusarium* spp., *Penicillium brevi-compactum*, *Penicillium* spp. and *Rhizopus stolonifer* and a bacterium, *Erwinia carotovora* were identified to be associated with yam tuber rots in Ghana (Aboagye-Nuamah *et al.*, 2005). Information regarding the role of bacteria in yam rot, however, is scanty (Osagie, 1992).

Fungal pathogens causing rots in yam often gain entry into tubers through wounds caused by insects, nematodes or poor handling before, during and after harvest (Amusa *et al.*, 2003; Ricci, 1979). Morse *et al.* (2000) reported that most of the yam rot induced by insect attacks are mainly due to storage beetles (*Coleoptera*), mealy bug (*Planococcus citri*) and scale insect (*Aspidiella hartii*) during storage. Controlling fungi and insects during storage is necessary to increase shelf life of yams.

## 2.8 CATEGORIES OF YAM ROT:

The storage diseases of yam can be categorized into three, based on the symptoms and the causal agents (Amusa and Baiyewu, 1999).

### 2.8.1 Dry rot

Dry rot symptoms vary with varying colouration, depending on the invading pathogen. When tubers are infected with *Penicillium oxalicum* and *P. cyclopium*, the tubers turn brown and then become hard and dry, maintaining their integrity, except when the tissues were invaded by *Sphaerostilbe marcescens* (IITA, 1993). Tissues invaded by *S. marcescens* become covered with the greenish mycelia of the fungus. Tubers infected with *Aspergillus niger* and *A. tamari* turn brown with yellowish margin. *Rosellina bunodes* and *B. theobromae* have also been reported to cause dry black rots. Tubers infected by the two organisms first turn grey and then black. These tubers become pulverulent and break into small dry particles (IITA, 1993).

### 2.8.2 Soft rot

Tubers infected by soft rot organisms often turn brown, soft and become wet due to rapid collapse of cell walls of tissues. Fungi associated with this type of rot are *Rhizopus sp.*, *Mucor circinelloides*, *Sclerotium rolfsii*, *Rhizoctonia solani* and *Armillariella mellea* (Ikotun, 1989; Amusa and Baiyewu, 1999).

### 2.8.3 Wet rot

Wet rot of yam tuber is characterized by the oozing of whitish fluid out of infected tissues when pressed. This symptom is usually associated with the bacterium, *Erwinia carotovora* (IITA, 1993; Amusa and Baiyewu, 1999).

## 2.9 STORAGE AND STORAGE SYSTEMS:

Water loss from tubers continues during storage and is significantly greater in tubers infected with *Sphaerostilbe bradys* compared to healthy tubers (Adesiyun *et al.*, 1975). Yam rots usually start at maturity in the field due to entry of wounds by rot-causing fungi or bacteria and progresses in storage. Regardless of the source of inoculum, most rot-inducing pathogens are unable to enter fleshy tissues except through open wounds. Tubers which are already attacked by rot pathogens when harvested are destroyed to a greater extent in storage. The rate at which this occurs depends upon the storage conditions (Osagie, 1992). Adeniji (1970) reported considerable reductions in rots caused by fungal organisms when tubers were stored in such a way that free air circulation was maintained, compared to stock piling them on the floor of a shed. Coursey and Nwanko (1968) demonstrated that a temperature of 50 °C causes tubers to lose weight and rot much more quickly than those kept in shade. These conditions must be prevented in

storage facilities. Optimum storage conditions for fungal growth on yam were also reported to be 22-29 °C and 80% relative humidity and above (Ogundana *et al.*, 1970). These conditions must be prevented in storage facilities.

## **2.10 CONTROL OF YAM TUBER ROT:**

Yam disease control has been extensively studied and several measures have been recommended. These include the use of crop rotation, fallowing and planting of healthy materials and the destruction of infected crop cultivars (Nwakiti, 1982; Ogundana *et al.*, 1970).

For post-harvest losses, the following control measures have been known to be effective in controlling rots:

1. Minimizing physical damage of tubers during post-harvest operations or handling.
2. If wounding cannot be entirely prevented, tubers may be placed in an environment favourable to rapid healing of wounds.
3. Treatment of yam tubers with fungicides such as Benlate and Captan just after harvest.

The boring beetle attack on shoot and tubers can be controlled by application of granular Diazinon and Carbofuran (Amusa *et al.*, 2003). Treatment of yam tubers with insecticide dust (Actellic 2% dust) will reduce insect pests attack and also ameliorate physical damages acquired during harvest, resulting in significantly fewer fungal lesions (Morse *et al.*, 2000).

Processing of yam tubers into chips will go a long way to reduce fungal attack. Yam farmers in south western Nigeria have been processing one-third of their harvested yam tubers into chips or cubes which can be stored between six months and one year (Amusa, 2001) as a means of reducing post-harvest losses associated with yam storage.

It has been reported that the most effective and desirable means of controlling field yam diseases is by the selection and planting of resistant cultivars (Nwakiti *et al.*, 1987).

Some biological control measures have been carried out, using microbes to control yam rot. Okigbo and Ikediugwu (2000) showed that *Trichoderma viride* displaced the naturally occurring mycoflora on the surface of the yam tuber. This simple application of *Trichoderma viride* effectively controls the normal tuber surface mycoflora throughout six months' storage, greatly reducing rotting. Okigbo and Nneka (2005) showed that extract of *Xylopi aethiopica* and *Zingiber officinale* controlled post-harvest yam rot. It has been reported that plants with fungicidal properties are very effective in inhibiting fungal growth *in-vivo* and *in-vitro* (Kuhn and Hargreaves, 1987). *C. alata* and *D. tripetala* are among the plants with such properties (Khan *et al.*, 2001).

#### **2.10.1 CHEMICAL FUNGICIDES:**

The use of synthetic chemicals such as sodium orthiophenylphenate, borax, captan, thiobendazole, benomyl, bleach (sodium hypochlorite) has been found to significantly reduce storage rot in yam (Booth, 1974; Noon, 1978,).

However, farmers in developing economies such as Nigeria have hardly adopted these findings, because the majority of them cannot afford the financial cost. Moreover,

chemical pesticides have the additional potential disadvantages of accumulation in the ecosystem and of induction of pesticide resistance in pathogens (Okigbo and Ikediugwu, 2000). There is also the problem of lack of expertise in the safe handling of pesticides among most of the farmers. Biological control is generally favoured as a method of plant disease management because it does not have the disadvantages of chemicals (Amadioha and Obi, 1999). Kuhn and Hargreaves (1987) observed that fungicidal substances found *in vitro* in most cases killed the fungus *in vivo*.

#### **2.10.1.1 MANCOZEB WP:**

Mancozeb is classified as a contact fungicide with preventive activity. It inhibits enzyme activity in fungi by forming a complex with metal-containing enzymes including those involved in the production of adenosine triphosphate (ATP). Mancozeb is used to protect many fruit, vegetable, nut and field crops against a wide spectrum of fungal diseases, including potato blight, leaf spot, scab on apples and pears, and rust on roses. It is also used for seed treatment of cotton, potatoes, corn, safflower, sorghum, peanuts, tomatoes, flax and cereal grains (SinoHarvest, 2005).

#### **2.10.1.2 SHAVIT F71.5WP (1.5% triadimenol+70% folpet):**

Shavit F71.5 WP is a systemic fungicide with protective and curative action against powdery mildew. Shavit F71.5 WP is a fungicide combining the systemic properties of triadimenol with the contact properties of folpet. Triadimenol belongs to the family of triazole fungicide and as such it is an inhibitor of biosynthesis of ergosterol. Triadimenol moves upwards in the vascular system and is distributed to give full protection to new

shoots. On the other hand, folpet acts as a protectant and has a contact action. It binds to sulphur-hydrogen bond, thereby interfering with respiration process in fungi (Makhteshim Chemical Works Limited-Israel).

#### **2.10.2 ANTIMICROBIAL PROPERTIES OF TRADITIONAL PLANTS:**

For thousands of years, natural products have been used in traditional medicine all over the world and predate the introduction of antibiotics and other modern drugs. The antimicrobial efficacy attributed to some plants in treating diseases has been beyond belief. It is estimated that local communities have used about 10% of all flowering plants on Earth to treat various infections, although only 1% have gained recognition by modern scientists (Kafaru, 1994).

Antibacterial activity of the essential oil, eugenol, purified from *Ocimum gratissimum* to treat pneumonia, diarrhea and conjunctivitis, has also been reported earlier (Nakamura *et al.*, 1999). Owing to their popular use as remedies for many infectious diseases, searches for plants containing antimicrobial substances are frequent (Betoni *et al.*, 2006).

Plant extracts have been used to control diseases in cowpea (Amadioha and Obi, 1998) and banana (Okigbo and Emoghene, 2004). Pesticides of plant origin are specifically more biodegradable, readily available, cheaper and environmentally friendlier than synthetic chemicals.

#### **2.10.2.1 *Cassia alata*:**

*Cassia alata* (family: Caesalpinaceae) is an erect tropical, annual herb with leathery compound leaves and yellow flowers. The leaves, flowers and seeds have been reported to contain high levels of anthraquinones, crysophanic, naphthoquinone, and hennotannic acids which have been demonstrated traditionally to treat ringworm, eczema, itching skin infections in humans and very effective inhibitors of mite infestations, bacterial and microbial diseases (Anderson *et al.*, 1999, Khan *et al.*, 2001; Adeboye *et al.*, 2002; Ali-Emmanuel *et al.*, 2003).

The extract from *C. alata* has variously been reported as possessing antimicrobial and insecticidal properties against wide ranges of microorganisms and insects. The efficacy of leaf powder and water extracts of *C. alata* against *S. rolfsii* causing soft rot of cocoyam cormel in storage was investigated and *C. alata* was effective as a bioprotector for cocoyam cormels (Nwachukwu and Osuji, 2008).

#### **2.10.2.2 *Zingiber officinale*:**

*Zingiber officinale*, the botanical name of the common ginger, was coined by the famous eighteenth-century Swedish botanist and general naturalist, Carl Linnaeus. About 1,400 species of plants are placed in the family *Zingiberaceae*. The ginger which is a perennial plant has a slender stem about 24 – 39 inches in height. The underground stem of ginger is the most familiar part of the plant and it is extensively used for commercial as well as domestic purposes. The habitat most suited to the cultivation of ginger is one with a hot

and moist climate with some shade; ginger also prefers soil that is well tilled and rich in loam (Herbs2000).

A lot of research has been carried out on the various herbal properties of ginger. The crop contains volatile oil, phenols, alkaloid and mucilage. The herbal therapeutic benefits of ginger are mainly due to the presence of volatile oils and the high oleoresin content. A compound known as *gingerol* is an acrid chemical constituent of the ginger and it is responsible for the hot taste of ginger and its stimulating effect on the human body. Ginger extracts have been extensively studied for a broad range of biological activities including antibacterial, anticonvulsant, analgesic, anti-ulcer, gastric anti-secretory, anti-tumor, anti-fungal, anti-spasmodic, anti-allergenic, and other activities (Foster and Yue, 1992).

A survey was conducted in Jaffna, Sri Lanka, to determine the local medicinal uses of ginger. The fungicidal properties of ginger rhizome extract were also evaluated. The growth inhibition on *Fusarium* spp., *Colletotrichum* spp. and *Curvularia* spp. by ginger rhizome extract were 70.0%, 71.0% and 64.2%, respectively (Krishnapillai, 2007).

Investigation was carried out to test the potency of some plant extracts for the control of yam tuber rot caused by *Fusarium oxysporum*, *Aspergillus niger* and *Aspergillus flavus*. Hot water extracts obtained from leaf and seed of uda (*Xylopia aethiopica*) and ginger (*Zingiber officinale*) were fungitoxic against the fungi. The extracts suppressed the growth of these fungi in culture and reduced rot development in yam tubers (Okigbo and Nmeka, 2005).

### 2.10.2.3 *Piper nigrum*:

*Piper nigrum* is one of the most common spices added to European cuisine and its descendants. The spiciness of black pepper is due to the chemical, *piperine* (1-piperoylpiperidine).

*Piper nigrum* (Black pepper) is a flowering vine in the family *Piperaceae*, cultivated for its fruit, which is usually dried and used as a spice and seasoning. The fruit, known as a peppercorn when dried, is a small drupe, approximately 5 millimetres (0.20 in) in diameter, dark red when fully mature, containing a single seed (Wikipedia, 2010). Black pepper is produced from the still-green unripe berries of the pepper plant. The berries are cooked briefly in hot water, both to clean them and to prepare them for drying. The heat ruptures cell walls in the pepper, speeding the work of browning enzymes during drying. The berries are dried in the sun or by machine for several days, during which the seed shrinks and darkens into a thin, wrinkled black layer. Once dried, the spice is called black peppercorn (Wikipedia, 2010).

Black Pepper (or long pepper) was believed to cure illnesses such as constipation, diarrhea, earache, gangrene, heart disease, hernia, hoarseness, indigestion, insect bites, insomnia, joint pain, liver problems, lung disease, oral abscesses, sunburn, tooth decay, and toothaches. It has been shown that piperine can dramatically increase absorption of selenium, vitamin B, beta-carotene and curcumin as well as other nutrients.

## **CHAPTER THREE**

### **MATERIALS AND METHODS**

#### **3.1 SURVEY TO DOCUMENT FARMERS KNOWLEDGE ON YAM TUBER**

##### **ROT DISEASES:**

Fifty two (52) farmers from four yam producing communities: Amponsakrom (Wenchi District), Kwabea and Abudwom (Kintampo South District) and Fiaso (Techiman District) all in the Brong Ahafo Region were interviewed by the use of structured questionnaires (Appendix 1) to find out farmers' knowledge of rot diseases as well as other relevant information such as storage methods practiced, crops cultivated, various yam varieties cultivated and pests and diseases that attack yam. The survey was conducted in 2009 and 2010.

##### **3.2 PATHOGENICITY STUDIES:**

###### **3.2.1 Collection of Diseased Yam Tubers:**

Rotten tubers of white yam variety ('pona') were collected from farms in three communities: Kwabea, Amponsakrom and Gbao (Tain District) and sent to the laboratory in polythene bags. Collected samples were kept in a refrigerator at 4°C until required.

###### **3.2.2 Isolation of Fungal Species from Rotten Yam Tubers:**

Pieces of diseased tissues cut from the periphery of rotten yam tubers with a sterilized knife were surface-sterilized in 5% sodium hypochlorite solution for 5 minutes. The surface sterilized diseased tissues washed three times using with sterile distilled water.

The tissues were allowed to dry in a sterile Lamina flow chamber. The dried disease tissues were plated on an artificial potato dextrose agar (PDA) medium (Manufacturer: Mearck). Four to five days after incubation, mycelia that grew from the plated yam tissues were sub-cultured onto fresh PDA. Further subculturing was carried out until pure cultures of single species isolates were obtained. From these pure cultures, inocula of the different fungal species isolates were obtained for the pathogenicity tests.

### **3.2.3 Identification of Fungal Isolates:**

Characteristics of fungal isolates from rotten yam tubers such as pigment production, colony texture, spore or conidia-producing structures and spore shapes were documented. The characteristics were observed from fungal tissues grown on PDA for one week or more, depending on the fungal species. Spore and mycelium characteristics were studied using the compound microscope. These characteristics were used in identifying the fungal organisms to the species level, following standards described by Mathur and Kongsdal (2003) and Barnett and Hunter (1972).

### **3.2.4 Pathogenicity Test:**

One week old pure cultures of the fungal isolates obtained from rotten yam tubers produced on PDA were the source of inocula for the pathogenicity studies. Healthy-looking yam tubers of the variety 'pona' were inoculated with the fungal isolates identified in section 3.2.3. A five-millimeter diameter cork borer was used to remove discs (1cm thick) from the yam tuber surface after surface sterilization of the tubers with 5% Sodium hypochlorite solution. The five-millimeter diameter cork borer (sterilized by dipping in alcohol followed by flaming) was used to cut plugs from the one week old

cultures of the fungal isolates to be tested. These fungal plugs were put in the holes created in the yam tubers after which the removed yam tuber discs were used to plug the holes. Melted candle wax from a burning candle was used to seal the edges of the replaced yam discs. This process prevented any external influence on the positioned inocula. Each fungal isolate was replicated three times (on three different yam tubers). Controls were set up in which the sterile cork borer was used to remove five-millimeter diameter tuber tissue. This disc was used to plug the hole and its edges sealed with melted wax. In the control, no fungal organism was placed in the hole. These activities were carried out inside a sterile hood.

### **3.3 CONTROL OF YAM TUBER ROT ORGANISMS WITH BOTANICAL EXTRACTS:**

#### **3.3.1 Preparation of extracts of botanicals:**

Cold water extraction method was used for the preparation of the botanical extracts. Fresh leaves of *Cassia alata*, rhizomes of *Zingiber officinale* and seeds of *Piper nigrum* were washed thoroughly with water. These were further blended into a fine paste separately for each botanical with a blender (Binatone, BLG-401, Hong Kong) at a speed of 4000 r.p.m. for five to ten minutes. Extract concentration of 60% (w/v) was obtained by adding 40mls of sterile distilled water to 60g of each botanical paste in a beaker with vigorous stirring. The efficacies of the botanical extracts were tested for their fungicidal activity in controlling yam tuber rot fungi.

### **3.3.2 Anti-fungal Activity of plant extracts *in vitro* on yam rot organisms:**

Two test fungi, *Botryodiplodia theobromae* and *Fusarium oxysporum*, obtained from rotten yam tissues, were used in this experiment. Surface coating of Potato dextrose agar (PDA) medium with botanical extracts was the method used to investigate the efficacy of the extracts. PDA medium was prepared by suspending 39g of product in one litre distilled water and autoclaving at 121°C for 15 minutes. The medium was poured into sterilized Petri dishes and allowed to solidify. Five hundred micro litres (500µl) of each botanical extract preparation was spread thinly on the surface of the PDA in Petri dishes. The extract was allowed to dry and the coated medium inoculated centrally with discs (5mm diameter) obtained from one-week-old cultures of the test fungi, *B. theobromae* and *F. oxysporum*. Three replications were set for each treatment. Controls were set up in which PDA with no botanical extract were inoculated with test fungi. Further controls were set-up in which PDA in Petri dishes were surface coated with a solution of Shavit F71.5 WP fungicide (at a concentration of 2g/L). The whole set-up was incubated at 28 °C and measurement of growth as radius of a growing fungal colony was undertaken at intervals of twenty-four hours using a ruler.

### **3.4 FIELD CONTROL OF YAM TUBER ROT WITH CHEMICAL FUNGICIDES:**

Efficacy of two chemical fungicides, Shavit F71.5 WP and Metalaxyl Mancozeb WP, in controlling yam tuber rot was investigated on-farm at two locations. At Amponsakrom, the efficacy of the two products was investigated, using the variety 'pona' and at Ejura,

(Ejura-Sekyere Odumase District, Ashanti Region) the two products were tested, using the variety 'dente'. At each location, nine pits were dug in a shade provided by a tree. Freshly harvested yam tubers selected for the experiments were sprayed with the two chemical fungicides. Shavit F71.5 WP was applied at a concentration of 2g/L (Manufacturer's recommendation), using a knapsack sprayer whilst Metalaxyl Mancozeb WP was applied at a concentration of 7.5g/L. After spraying, the tubers were allowed to dry in a shade after which tubers (fifteen per treatment) were buried in each pit. After burial, each pit was further covered with cut vegetation. The treatments were completely randomized with controls (no chemical applied). The experiments were set up in December 2009 and monitored regularly for signs of sprouting. The tubers were removed and examined when signs of sprouting were observed. The numbers of unrotten and rotten tubers in each pit were recorded both at Amponsakrom and Ejura. The effectiveness of the chemical fungicides in reducing yam tuber rot disease was determined. The Decay Reduction Index (Amadioha, 1996) defined below, was calculated as a measure of the effectiveness of each chemical fungicide in controlling yam rot after final data collection.

$$D.R.I. = \frac{\%decay \text{ in control} - \%decay \text{ in treated tuber}}{\%decay \text{ in control}}$$



Figure 2: Inoculation of healthy-looking yam tubers with fungal isolates to test their pathogenicity.

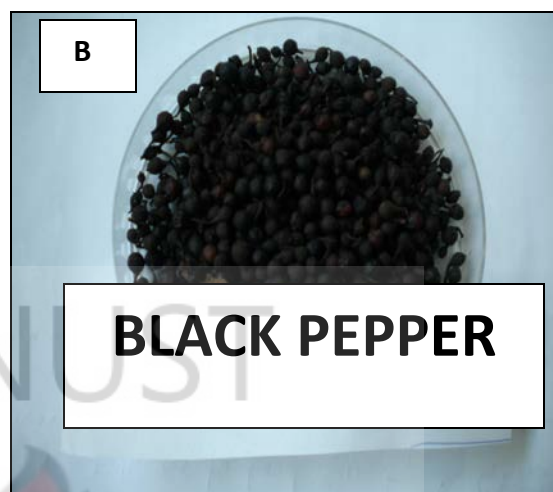


Figure 3: Botanicals whose extracts were tested for anti-fungal activity.

A-: *Zingiber officinale* rhizomes

B-: *Piper nigrum* seeds

C-: *Cassia alata* leaves

## CHAPTER FOUR

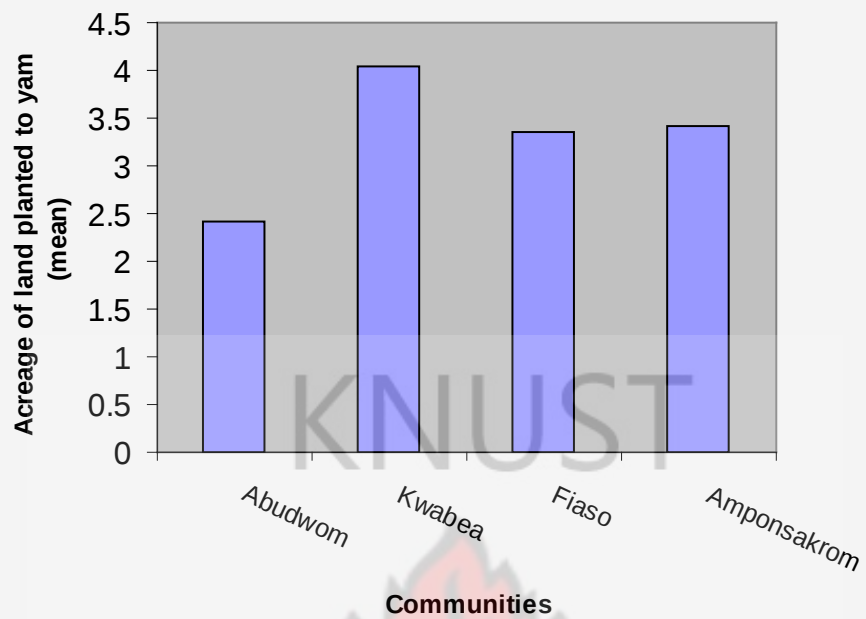
### RESULTS

#### 4.1 CROPS PRODUCED BY FARMERS IN SURVEYED COMMUNITIES:

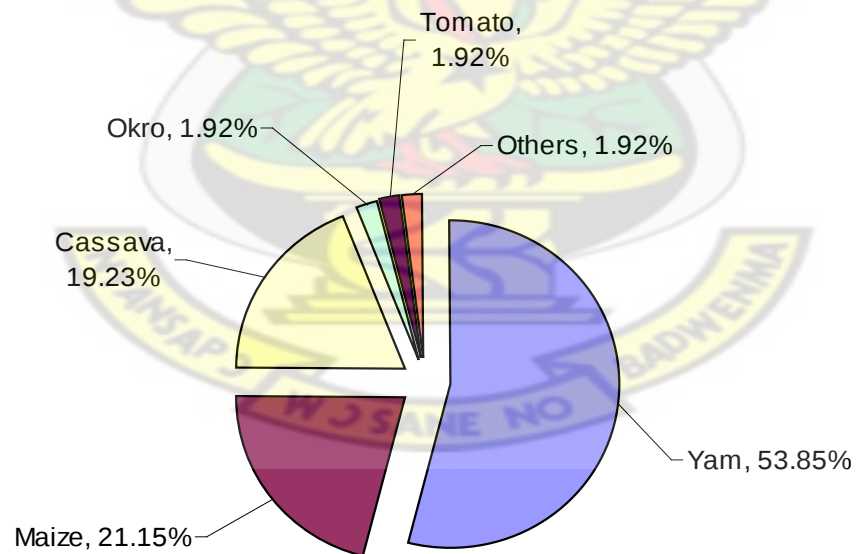
The farmers are engaged in small scale farming where the family members are all part of the labour force used on the farm. The average age of farmers interviewed ranged between thirty-nine (39) and forty-eight (48) years with seventy-five percent (75%) of them being males. The average acreage of cultivated land for the farmers at Kwabea, Amponsakrom, Fiaso and Abudwom are 4.0, 3.5, 3.5 and 2.5 acres, respectively (see Figure 4).

Crops such as yam, maize, cassava and cowpea are considered to be the major crops that are cultivated in the communities (see Table 1). Fifty four percent (54%) of the farmers interviewed ranked yam as their most important crop in terms of income generation and food security (see Figure 5). Millet, sweet potato, cocoyam, groundnut and vegetables such as garden eggs, pepper, okro and tomato are cultivated on small scale.

Some of the white yam varieties produced by most of the farmers are ‘pona’, ‘lily’, ‘kawkaw’, ‘labreko’, ‘borodwoma’, ‘dente’, ‘asobayere’, ‘muchumudu’ and ‘lawbayere’. A water yam variety, ‘afase’ is also cultivated by few farmers to increase their income and improve food security.



**Figure 4: Mean land acreages cultivated to yam in the studied communities.**



**Figure 5: Crops that help farmers to achieve food security in the studied communities.**

Table 1: Frequency of crops cultivated by farmers in studied communities.

| <b>Crop</b>  | <b>Frequency of farmers cultivating these crops</b> |        |       |             | <b>Total</b> |              |
|--------------|-----------------------------------------------------|--------|-------|-------------|--------------|--------------|
|              | Abudwom                                             | Kwabea | Fiaso | Amponsakrom | <b>Freq.</b> | <b>%</b>     |
| Yam          | 13                                                  | 13     | 14    | 11          | <b>51</b>    | <b>98.08</b> |
| Tomato       | 2                                                   | 4      | 0     | 3           | <b>9</b>     | <b>17.31</b> |
| Maize        | 13                                                  | 13     | 10    | 10          | <b>46</b>    | <b>88.46</b> |
| Pepper       | 2                                                   | 4      | 3     | 0           | <b>9</b>     | <b>17.31</b> |
| Cassava      | 4                                                   | 13     | 14    | 6           | <b>37</b>    | <b>71.15</b> |
| Cashew       | 0                                                   | 5      | 0     | 3           | <b>8</b>     | <b>15.39</b> |
| Teak         | 0                                                   | 1      | 0     | 0           | <b>1</b>     | <b>1.92</b>  |
| Beans        | 4                                                   | 3      | 1     | 4           | <b>12</b>    | <b>23.08</b> |
| Millet       | 0                                                   | 1      | 0     | 2           | <b>3</b>     | <b>5.77</b>  |
| G. Eggs      | 0                                                   | 2      | 1     | 0           | <b>3</b>     | <b>5.77</b>  |
| Mango        | 0                                                   | 2      | 0     | 0           | <b>2</b>     | <b>3.85</b>  |
| Sweet Potato | 2                                                   | 0      | 6     | 0           | <b>8</b>     | <b>15.39</b> |
| Cocoyam      | 1                                                   | 0      | 4     | 0           | <b>5</b>     | <b>9.62</b>  |
| Groundnut    | 0                                                   | 0      | 1     | 2           | <b>3</b>     | <b>5.77</b>  |
| Okro         | 0                                                   | 0      | 1     | 3           | <b>4</b>     | <b>7.69</b>  |

#### 4.2 FARMERS' KNOWLEDGE OF DISEASES:

Pest and disease attack is one of the major constraints to production of yam in the communities surveyed. The interviewed farmers ranked pests and diseases as their number two constraint after acquisition of credit (see Table 2). Some of the pests that were described by the interviewed farmers were termites, caterpillars, aphids, beetles and nematodes. With respect to farmers' knowledge on diseases that attack yam, yam mosaic virus (YMV) disease, rot and anthracnose were considered to be common in those communities (see figure 6).

Yam tuber rot was considered by sixty five percent (65%) of interviewed farmers as a major problem. According to these farmers, they sometimes lost nearly all their stored tubers due to rot. One hundred percent (100%) of the interviewed farmers who stored their yams indicated that they experienced rots during post-harvest storage of tubers. Although most of these farmers interviewed could not quantify losses due to rot diseases, on the average, they lost over sixty percent (60%) of their tubers during storage.

In controlling pest attack, about twenty five percent (25%) of those who stored yam tubers in barns used baits to trap rodents. None of the responding farmers used chemicals (fungicides) or other products to protect their tubers from rots (see figure 7).

Sixty nine percent (69%) of the farmers stored harvested yam tubers either by soil burying, heaping and covering, gradual harvesting or storage in barns. For those who stored tubers, twenty one percent (21%) of them store their yam tubers on-farm by burying (Figure 8). Pits of about 1m wide and 0.5m to 1m deep were dug in a shaded area and the tubers were placed vertically in the pits and covered with dug-out soil and dry

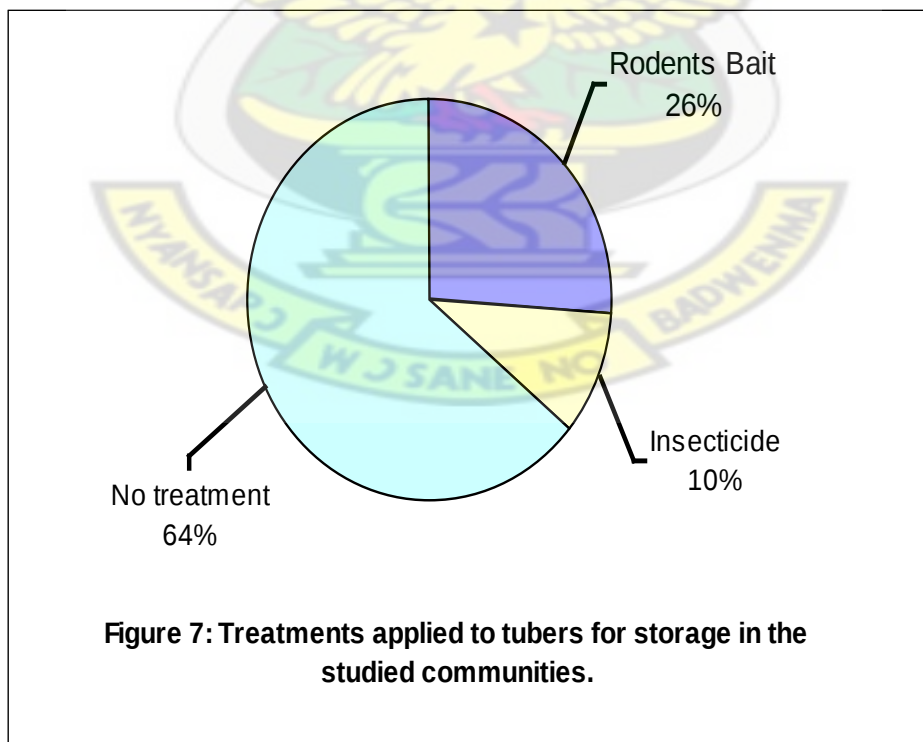
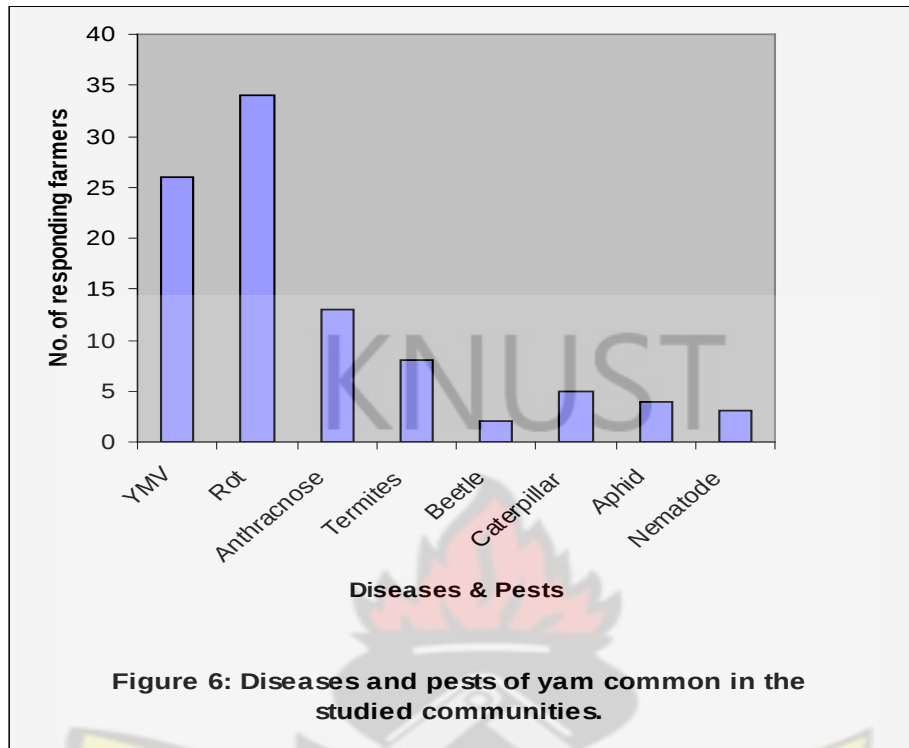
vines and cut grass. Yam barns, normally made with dry palm fronds, were common in the areas surveyed, especially for storing seed yams for next planting season. Few farmers said they could store tubers of certain white yam cultivars up to six months but most of them said their storage periods were between three and 12 weeks, depending on variety.

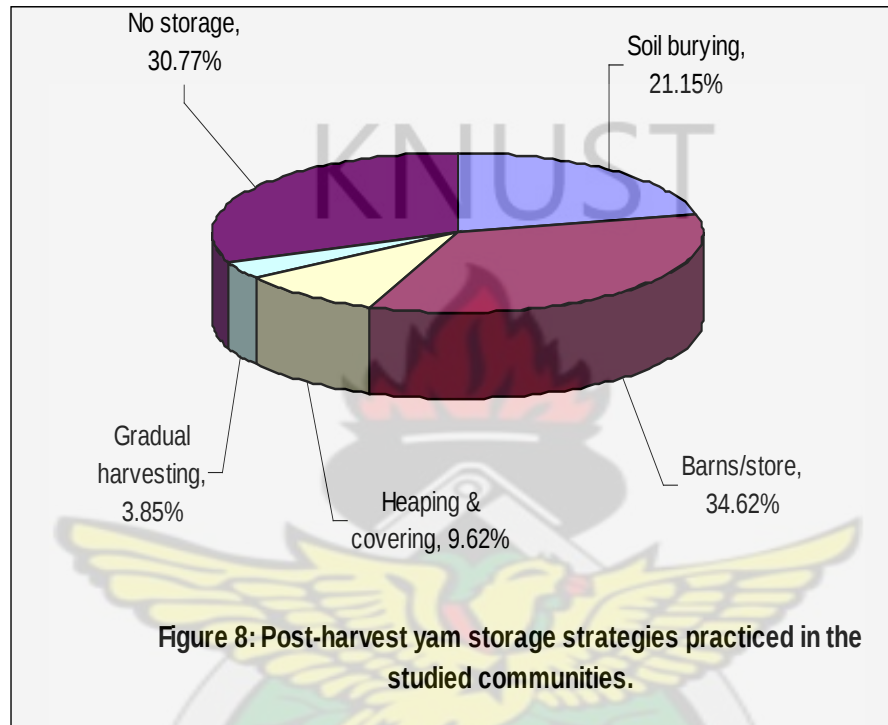
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Table 2: Constraints that affect yam production in the studied communities.

| Constraints                          | Frequency of farmers in response to constraints |        |       |             | Total |       |
|--------------------------------------|-------------------------------------------------|--------|-------|-------------|-------|-------|
|                                      | Abudwom                                         | Kwabea | Fiaso | Amponsakrom | Freq. | %     |
| Finance/ Capital                     | 8                                               | 12     | 10    | 7           | 37    | 71.15 |
| Pest & Diseases                      | 5                                               | 4      | 4     | 8           | 21    | 40.39 |
| Land acquisition difficulty          | 1                                               | 2      | 1     | 4           | 8     | 15.39 |
| Agro-chemicals                       | 0                                               | 3      | 0     | 0           | 3     | 5.77  |
| Market price for produce             | 2                                               | 3      | 0     | 0           | 5     | 9.62  |
| Weather/Climate                      | 0                                               | 1      | 0     | 0           | 1     | 1.92  |
| Cost of labour                       | 4                                               | 2      | 5     | 5           | 16    | 30.77 |
| Non-sprouting of yam setts           | 0                                               | 0      | 4     | 0           | 4     | 7.69  |
| Unavailability of planting materials | 3                                               | 0      | 2     | 0           | 5     | 9.62  |
| Transportation                       | 0                                               | 0      | 1     | 0           | 1     | 1.92  |
| Soil productivity                    | 0                                               | 0      | 0     | 1           | 1     | 1.92  |
| Continuous farming                   | 0                                               | 0      | 0     | 1           | 1     | 1.92  |
| Cultural practices                   | 2                                               | 0      | 0     | 4           | 6     | 11.54 |





#### 4.3 IDENTIFICATION OF FUNGAL ISOLATES AND PATHOGENICITY STUDIES:

Based on cultural and microscopic characteristics of conidia, the nine isolates of fungi obtained from rotten tubers were identified as *Fusarium oxysporum*, *Aspergillus flavus*, *Aspergillus niger*, *Penicillium* sp., *Botryodiplodia theobromae*, *Trichoderma viride*, *Rhizopus* sp., *Pestalotia guepini* and *Alternaria solani*, following descriptions of Mathur and Kongsdal (2003) and Barnett and Hunter (1972). Figure 9 shows the conidia of some of the fungal isolates from rotten yam tissues produced on PDA.

Each of these isolates was able to cause rot lesions when inoculated into healthy-looking yam tubers. Koch's postulate was established with each isolate through re-isolation. Figure 10 shows rot lesions caused by *Penicillium* spp. inoculated into a healthy yam tuber. *B. theobromae*, *A. niger*, *Rhizopus* spp. and *A. solani* were the most frequently isolated fungal species from the rotten yam tubers collected from the study districts. The frequency of isolation was in the order of 30.07%, 16.08%, 16.08% and 12.59% respectively. All the fungal species isolated caused dry rot except *Rhizopus* spp. and *A. flavus*, which caused soft rot.

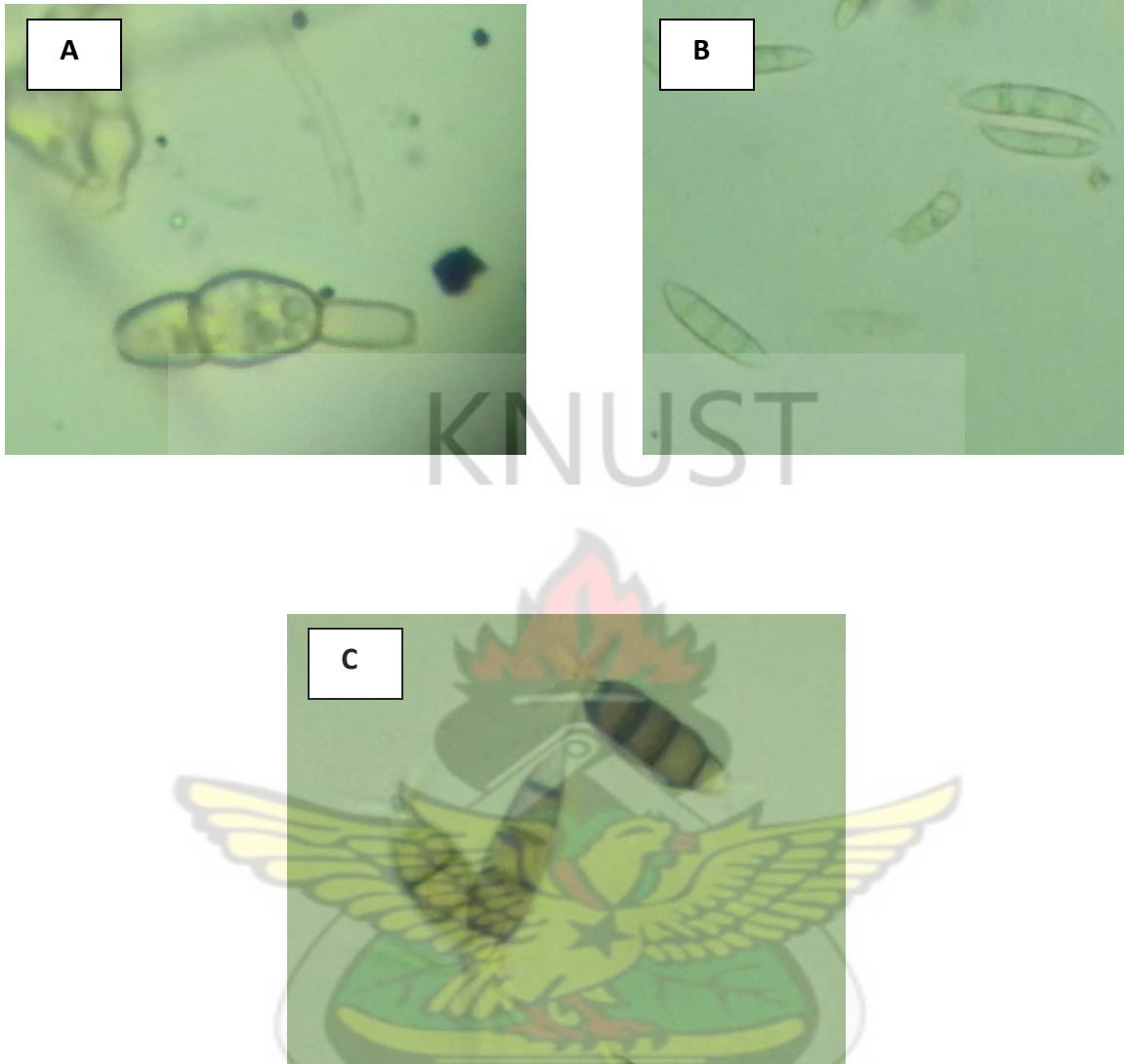


Figure 9: Conidia of some fungi identified (from rotten yam tissues) under high power of compound microscope.

A-: *Alternaria solani*

B-: *Fusarium oxysporum*

C-: *Pestalotia guepini*



Figure 10: A cross-section of a tuber of yam inoculated with *Penicillium* spp. showing rot lesion.

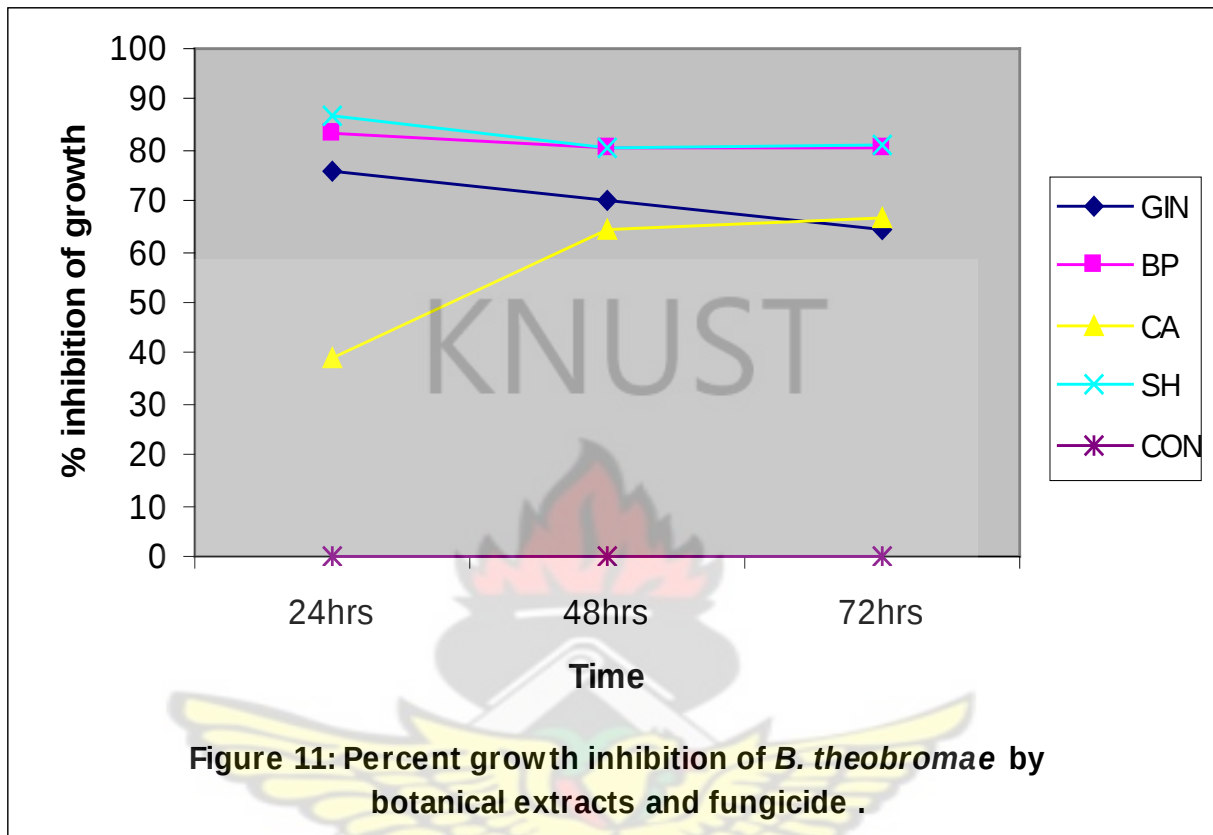
#### **4.4 CONTROL OF YAM TUBER ROT ORGANISMS WITH BOTANICAL EXTRACTS:**

##### **4.4.1 Effectiveness of plant extracts in controlling *B. theobromae* isolated from yam tuber rot tissues:**

In this study, percent inhibition of the growth of the fungal organism due to the botanical extracts is used to represent activity of the product. After 24 hours incubation, ginger rhizome extract inhibited growth of *B. theobromae* by 76.12% when compared with the control. This activity declined to 70.16% at the end of 48 hours period and reduced to 64.64% 72 hours after incubation (Figure 11).

Black pepper seed extract at a concentration of 60% (w/v) inhibited growth of *B. theobromae* by 83.58%, 80.65% and 81.23% after 24 hours, 48 hours and 72 hours incubation, respectively (Figure 11).

Activity of Cassia leaf extract at a concentration of 60% (w/v) was 38.81% after 24 hours incubation. The activity of the plant extract increased to 64.52% after 48 hours before moving to 66.85% at the end of 72 hours incubation (Figure 11).



**KEY:**

GIN = Ginger rhizome extract

BP = Black pepper seed extract

CA = *Cassia alata* leaf extract

SH = Shavit F71.5 WP

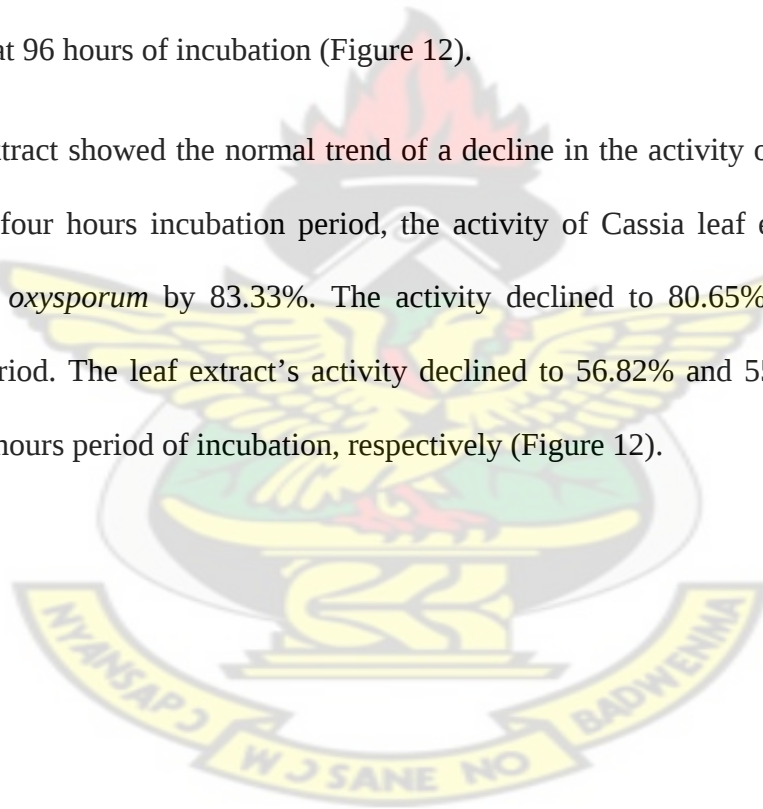
CON = Control

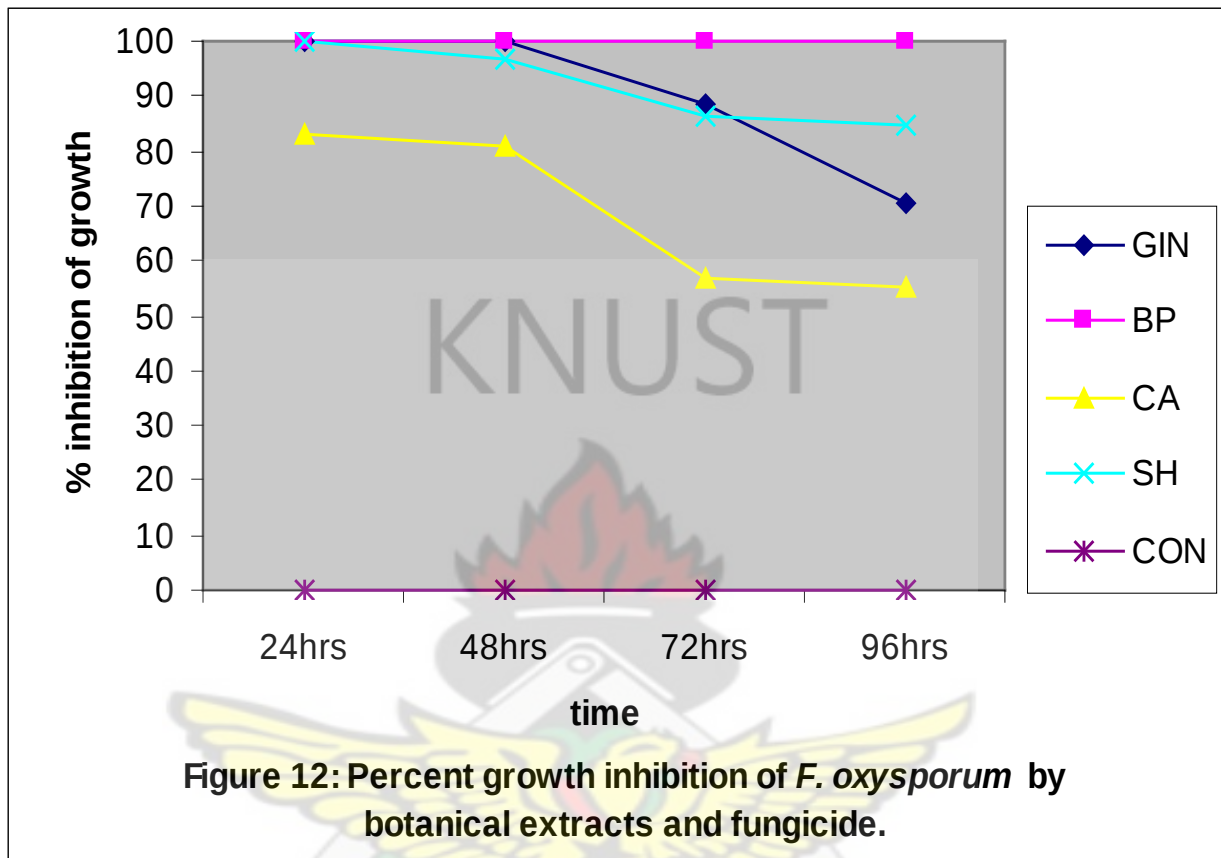
#### **4.4.2 Effectiveness of plant extracts in controlling *F. oxysporum* isolated from yam tuber rot tissues:**

The percent growth inhibition of *F. oxysporum* by ginger rhizome leaf extract (60% concentration) after 24 hours and 48 hours incubation was 100%. Activity in the extract declined to 86.36% and 70.69% at the end of 72 hours and 98 hours, respectively (Figure 12).

One hundred percent (100%) growth inhibition of *F. oxysporum* was achieved with Black pepper, even at 96 hours of incubation (Figure 12).

Cassia leaf extract showed the normal trend of a decline in the activity of plant extracts. After twenty four hours incubation period, the activity of Cassia leaf extract inhibited growth of *F. oxysporum* by 83.33%. The activity declined to 80.65% after 48 hours incubation period. The leaf extract's activity declined to 56.82% and 55.17% at the 72 hours and 96 hours period of incubation, respectively (Figure 12).





**KEY:**

GIN = Ginger rhizome extract

BP = Black pepper seed extract

CA = *Cassia alata* leaf extract

SH = Shavit F71.5 WP

CON = Control

Table 3: Anti-fungal activities of botanical extracts on *B. theobromae* and *F. oxysporum*.

| Botanical Extract    | Incubation Period (hours) | Fungicidal Activity ( as % growth inhibition) |                     |
|----------------------|---------------------------|-----------------------------------------------|---------------------|
|                      |                           | <i>B. theobromae</i>                          | <i>F. oxysporum</i> |
| <i>Z. officinale</i> | 24                        | 76.12                                         | 100                 |
|                      | 48                        | 70.16                                         | 100                 |
|                      | 72                        | 64.64                                         | 88.64               |
| <i>P. nigrum</i>     | 24                        | 83.58                                         | 100                 |
|                      | 48                        | 80.65                                         | 100                 |
|                      | 72                        | 80.66                                         | 100                 |
| <i>C. alata</i>      | 24                        | 38.81                                         | 83.33               |
|                      | 48                        | 64.52                                         | 80.65               |
|                      | 72                        | 66.85                                         | 56.82               |

#### **4.5 CONTROL OF YAM TUBER ROT WITH CHEMICAL FUNGICIDES ON-FARM:**

The buried yam tubers in this study were exhumed and examined 14 weeks after storage at Ejura. The average percent rots recorded for Shavit WP, Metalaxyl Mancozeb WP and control were 15.55%, 28.89% and 53.33%, respectively (see Appendix 2). This implies that eighty five percent (85%) and seventy one percent (71%) of the stored tubers were protected by the application of Shavit WP and Mancozeb Metalaxyl WP, respectively. These values were analysed, using the Decay Reduction Index method. Shavit WP had a DRI of 0.71 whilst Metalaxyl Mancozeb had 0.46. Though the two fungicides were able to reduce rot pathogen infections, Shavit WP was more potent than Metalaxyl Mancozeb WP.

The white yam variety, 'pona', was also tested at Amponsakrom. The recorded percent rot after 14 weeks in storage for Shavit WP, Metalaxyl Mancozeb WP and control were 6.67%, 8.89% and 22.22%, respectively (Appendix 3). The DRI value for Shavit WP was 0.70 whilst 0.60 was the DRI for Metalaxyl Mancozeb WP (Figure 13). The decay reduction index values for both fungicides show that they are all effective in reducing the incidence of rot disease during post-harvest storage. The tubers that were not rotten looked very healthy and fresh (Figure 14).

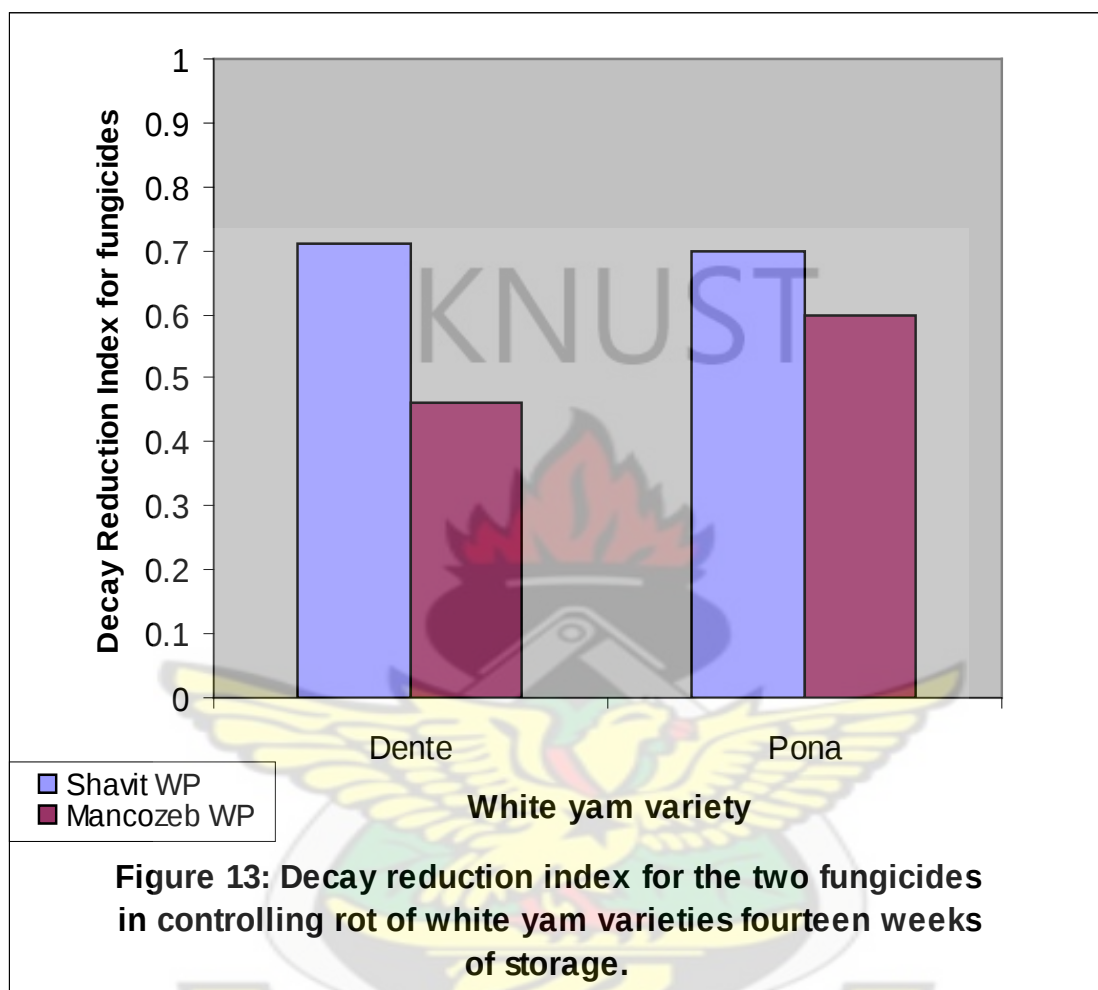




Figure 14: Cross-section of tubers treated with Shavit WP fourteen weeks after burial.

## CHAPTER FIVE

### DISCUSSION

Yam is a valuable source of carbohydrates to most people in the tropics and subtropics (Coursey, 1967). Yam production in Ghana forms an integral part of our goal of ensuring food security. The availability of yam on the market for a considerable part of the year helps prevent food shortages, particularly in the urban communities because of its relatively longer shelf life, compared with other root crops. Over fifty percent of the interviewed farmers ranked yam as their most important crop in generating income and ensuring food security. This means that farmers in these communities are mostly yam growers. Most of the varieties cultivated by the farmers in the four communities are white yams (*D. rotundata*) and this agrees with the fact that it is much preferred to than the other yam varieties and constitutes about 80% of total yam produced in Ghana (Tetteh and Saakwa, 1994). Water yams (*D. alata*) are consumed when white yam becomes scarce or expensive.

The farmers in the communities indicated that disease problems are the second most important problem which needs much attention after availability of financial credits. Sixty five percent of the responding farmers consider yam tuber rot to be a major problem confronting yam production in these communities. This confirms a rapid rural appraisal (RRA), carried out in January 1998, which revealed that farmers considered pest and disease problems to be the second most important constraint to yam production after financial considerations (Peters, 2000).

Yam tuber rot disease is associated with post-harvest handling of yam tubers. Losses due to this disease scare some farmers from storing some of their harvested produce. The incidences of rot greatly affect the quality of tubers, income generation, food security and farming engagements in the next planting season. Storage rot is part of the three fungal diseases that is of economic significance throughout the world (Vinayaka *et al.*, 2009). From the survey, if hundred percent (100%) of farmers who store their yams experience rot disease during storage and the average percent rot is over sixty percent (60%), then losses due to tuber rot disease is on the high side. This situation may exist in other yam producing communities in Ghana. In Nigeria, Adesiyun and Odihirin (1975) reported that post harvest losses of tubers could be as high as eighty percent (80%) during storage. Though the farmers know how yam tuber rot disease affects their incomes and food security, they practically do nothing to control losses caused by rots.

A significant deduction from the survey is that some farmers attribute the occurrence of rot to heat and reduced ventilation. Thus, farmers know the conducive conditions that would reduce the incidence of rot. However, fungi are considered the principal causal organisms of yam rot disease but none of the interviewed farmers apply any chemical or other products to protect their stored tubers against rots during storage. The farmers need education on how to protect their tubers from rots.

Some of the major microorganisms causing rot diseases in yams include *Aspergillus flavus*, *Aspergillus niger*, *Botryodiplodia theobromae*, *Fusarium oxysporum*, *Fusarium solani*, *Penicillium chrysogenum*, *Rhizoctonia* spp., *Penicillium oxalicum*, *Trichoderma viride* and *Rhizopus nodosus* (Adeniji, 1970; Okigbo and Ikediugwu, 2001; Okigbo, 2004; Aidoo, 2007). Seven of these fungi were isolated and identified to be rot-causing

organisms in this study. *B. theobromae* and *Penicillium* spp. are reported to cause dry rot of yam (IITA, 1993), whilst *Rhizopus* spp. causes soft rot (Amusa and Baiyewu, 1999). *Alternaria solani* and *Pestalotia guepini* were found in this work to cause rots of yam.

Little work has been done to investigate the use of natural plant products as pesticides for the control of post-harvest storage rot diseases of yam (Okigbo and Nmeko, 2005). Pesticides of plant origin are known to be more specific, biodegradable, cheaper, more readily available and environmentally friendlier than synthetic chemicals. The efficacies of the three botanical extracts (*Z. officinale*, *P. nigrum* and *C. alata*) in controlling yam tuber rot fungi were significant. The antifungal properties of *Xylopiya aethiopica* and *Z. officinale* against some spoilage fungi responsible for yam tuber rot in storage have been studied in Nigeria (Okigbo and Nmeko, 2005).

The rhizome extract of *Z. officinale* was active in inhibiting growth of *F. oxysporum* and *B. theobromae* in this work. This confirms the work done by Okigbo and Nmeko (2005) that *Z. officinale* suppresses the growth of rot fungi in culture and reduces rot development in yam tubers. *Z. officinale* contains an active ingredient called *gingerol*. Ginger rhizome extracts have been shown to possess a broad range of biological activity against fungi (Foster and Yue, 1992).

*P. nigrum* has been shown to possess anti-fungal properties because of the presence of an active ingredient called *piperine*. In this study *P. nigrum* exhibited fungistatic activity against *B. theobromae* and *F. oxysporum* by inhibiting their growth.

*C. alata* was less effective in controlling the growth of *B. theobromae* and *F. oxysporum*. *C. alata* has variously been reported as possessing antimicrobial properties against a wide

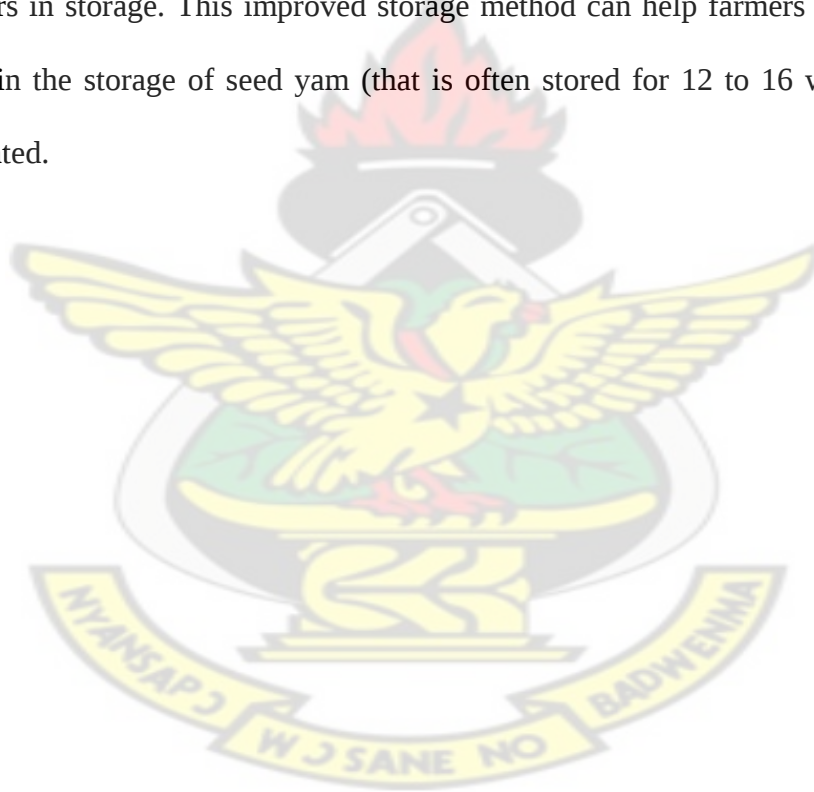
range of microorganisms and insects (Nwachukwu and Osuji, 2008). Results from this work, however, indicate that *B. theobromae* and possibly other fungal organisms possess the ability to metabolise *C. alata* extracts. This needs further investigation. The results being reported on were conducted in the laboratory. Situation on-farm or in storage barns may differ from those in laboratories. It is important that a thorough investigation on the effectiveness of *P. nigrum* (for example) in controlling tuber rot is carried out on-farm.

There have been some attempts to control post-harvest rots by improving storage methods. In order to improve the shelf life of stored tubers, the surfaces of the tubers have to be protected before storage. Soil burying is a common storage practice in the studied communities. They normally cover the stored tubers with the clayey part of the dug-out soil to prevent sprouting. Rot organisms gain entry into tubers through wounds caused by insects, nematodes or poor handling before, during and after harvest. Since wounds cannot be entirely prevented especially during harvesting, there is a need to protect the surface of tubers against the entry of rot organisms or kill pathogens that have filled wounds at harvest with appropriate protectants such as fungicides.

The two chemical fungicides, Shavit F71.5 WP and Metalaxyl Mancozeb WP, which were applied, were to offer that protection to the tubers against pathogens. Shavit WP had D.R.I. values of 0.71 and 0.70 for the two yam varieties, 'dente' and 'pona', respectively. This implies that the chemical (Shavit WP) can reduce the occurrence of yam tuber rot disease by seventy percent (70%) during storage of yam tubers. The D.R.I. value of Metalaxyl Mancozeb WP in controlling rot of 'dente' was 0.46 and that of 'pona' was 0.60. Thus, this chemical fungicide is capable of reducing rot of yam tubers by forty six percent (46%) for 'dente' and sixty percent (60%) for 'pona'. The results for the two

chemical fungicides show potency in controlling the disease during storage. However, Shavit WP is relatively more potent than Metalaxyl Mancozeb in terms of reducing decay of yam tubers. It had the highest DRI values for the two white yam varieties ('dente' and 'pona'). Few experiments have been done by researchers on the control of yam tuber rot disease with chemical fungicides. Chemical fungicides such as Benlate and Captan, however, have been found to be effective in reducing rots of yams (Ogundana, 1981).

The two tested chemical fungicides can be depended on by farmers to increase shelf life of yam tubers in storage. This improved storage method can help farmers reduce losses particularly in the storage of seed yam (that is often stored for 12 to 16 weeks) before they are planted.



## CHAPTER SIX

### CONCLUSIONS AND RECOMMENDATIONS

#### Conclusions

Ghana is the number one exporter of yam in the world with an annual export of 12,000 tonnes. Yam contributes significantly to our food security. Income generated from yam production helps improve the living standards of farmers. Post-harvest storage of yam tubers is very important to ensure continuous availability of the tubers on the market.

The principal causal organisms of yam tuber rot disease are known to be fungal pathogens. Hundred percent (100%) of the interviewed farmers do not protect their tubers with fungicides or any other products against these pathogens. It can, therefore, be concluded that losses in storage can be huge. Estimated losses given by the farmers range between 60% and 100%.

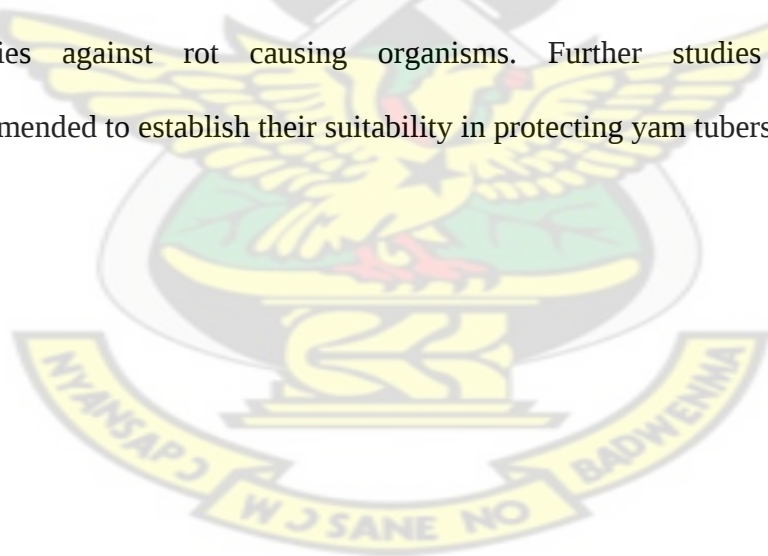
Results from this study indicate that Shavit WP and Metalaxyl Mancozeb WP can be used as chemical protectants in controlling yam tuber rot if applied as determined in this study. Surface coating of white yam tubers with these chemical fungicides prior to storage in pits or barns would reduce the incidence of rot diseases and increase shelf life of yam tubers. Additionally, seed yams for next cropping season, which are expensive, can be protected against rots with the use of these chemical fungicides.

The extracts of *Z. officinale* and *P. nigrum* have anti-fungal activities against fungal pathogens which cause yam tuber rot disease. It is recommended that the protective

functions of the two botanicals on actual tubers are investigated before specific recommendations are made.

### Recommendations

- Shavit F71.5 WP and Metalaxyl Mancozeb may be applied at manufacturer's recommended rate to protect seed yams against tuber rot disease of yam.
- Though the two chemicals can protect ware yams, it is recommended that further experiments are conducted after treatment and storage to determine the presence or absence of chemical residues in the tubers after the storage period.
- Botanical extracts of *Z. officinale* rhizomes and *P. nigrum* seeds have anti-fungal activities against rot causing organisms. Further studies are however recommended to establish their suitability in protecting yam tubers.



## CHAPTER SEVEN

### REFERENCES

1. Aboagye-Nuamah F., S.K. Offei, E.W. Cornelius and R.D. Bancroft (2005). Severity of spoilage storage rots of white yam (*Dioscorea rotundata* Poir.) **Annals of Applied Biology**; **147(2)**. 183-190 pp
2. Adeboye O., W.A. Anderson, M. Moo-Young, and V. Snieckus (2002). Kinetics of Antibacterial Activity and Physicochemical Damage Caused by the Extracts of *Senna alata* Flowers. **Pharmaceutical Biology**; **40(6)**: 461pp.
3. Adeniji M.O. (1970). Fungi associated with storage decay of yam in Nigeria. **Phytopathology**. **60**: 590-92.
4. Adesiyan S.O. and R.A. Odihirin (1975). Histopathology studies of the yam tuber (*Dioscorea rotundata* Poir) infected with *Scutellonena bradys* (Steiner & Hettew). **International Biodeterioration Bulletin** **11**. pp 48-55
5. Aidoo K.A. (2007). Identification of yam tuber rot fungi from storage systems at the Kumasi Central market. A dissertation submitted to Faculty of Agriculture, K.N.U.S.T.; 18-19 pp
6. Ali-Emmanuel N., M. Moudachirou, J.A. Akakpo and J. Quetin-Leclercq (2003). Treatment of bovine dermatophilosis with *Senna alata*, *Lantana camara* and *Mitracarpus scaber* leaf extracts. **Journal of Ethnopharmacology**; **86(2/3)**: 167pp.
7. Amadioha A.C. (1996). Control of storage rot of potato caused by *Rhizopus oryzae*. **Int. J. Pest Manage.** 52:311-314.

8. Amadioha A.C. and V.I. Obi (1998). Fungi toxic activity of extracts of *Adiradichta indica* and *Xylopia aethiopica* on *Colletotrichum lindemuthianum* in cowpea. **J. Herbs, Spice and Medicinal Plants (In press).**
9. Amusa N.A., A.A. Adegbite, S. Muhammed and R.A. Baiyewu (2003). Yam diseases and their management in Nigeria. **African Journal of Biotechnology Vol. 2(12).** 497- 502 pp
10. Anderson W.A., O. Adedayo, M. Moo-Young and D.O. Kolawole (1999). Antifungal Properties of Some Components of *Senna alata* Flower. **Pharm. Biology; 37(5):** 33pp.
11. Barnett H.L. and B.B. Hunter (1972). Illustrated Genera of Imperfect Fungi. 3<sup>rd</sup> Edition. **Burgess Publishing Company.**
12. Betoni J.E.C., R.P. Mantovani, L.N. Barbosa, L.C. Di-Stasi and A. Fernandes (2006). Synergism between plant extract and antimicrobial drugs used on *Staphylococcus aureus* diseases. **Mem. Inst.Oswaldo Cruz, 101.** 387-390pp.
13. Booth R.H. (1974). Post-harvest deterioration of tropical root crops. Losses and their control. **Trop. Sci. 16(2).** Pp 49-63.
14. Coursey D.G. (1967). Yams. **Longmans, London.** 230pp
15. Encarta encyclopedia (2006)
16. F.A.O. report (1998). FAO Annual Report. **Food and Agriculture Organisation Production Year Book.** FAO Rome
17. F.A.O. report (2005).FAO Annual Report. **Food and Agriculture Organisation Production Year Book.** FAO Rome

18. Foster S. and C.X. Yue (1992). Herbal Emissaries: Bringing Chinese Herbs to the West. **Rochester, Vt: Healing Arts Press.**
19. Herbs2000. Ginger ([www.herbs2000.com/Ginger](http://www.herbs2000.com/Ginger), date accessed: 9-08-09)
20. I.I.T.A. (1993). Crops Improvement Division/ Tuber root Improvement Program Archival Reports (1989-1993). **Part III yam. Ibadan, Nigeria.** Pp 20-85
21. Ikotun T. (1989). Diseases of yam tubers. **International Journal of Tropical Plant Diseases (India).** Pp 21.
22. Kafaru E. (1994). Immense help formative workshop. In Essential Pharmacology. 1st Ed. **Elizabeth Kafaru Publishers: Lagos, Nigeria.**
23. Kay D.E. (Revised by Gooding E.G.B.) (1987). Crops and product digest No. 2 Root crops (second edition). **London Tropical Development and Research Institue.** 380 pp
24. Khan M.R., M. Kihara and A.D. Omoloso (2001). Antimicrobial activity of *Cassia alata*. **Fitoterapia, 72:** 561-564pp.
25. Kochlar S.L. (1981). Tropical Crops, a Text Book of Economic Botany. **Mcmillan Int.** 469 pp
26. Krishnapillai N. (2007). Medicinal value of ginger (*Zingiber officinale*) in Jaffna. **Department of Botany, University of Jaffna, Jaffna, Sri Lanka.** [www.cabi.org/CABI](http://www.cabi.org/CABI) abstract.
27. Kuhn P.J. and J.A. Hargreaves (1987). Antifungal substances from herbaceous plants. In: FG Peggs and AG Ayes (eds). Fungal infection of plants. **Symposium of the British Mycol. Soc. CambridgeUni. Press.** 48-129 pp.

28. Makhteshim Chemical Works Ltd. ([www.makhteshim.co.il](http://www.makhteshim.co.il), date accessed 27-11-09).
29. Marthur S.B. and O. Kongsdal (2003). Common Laboratory Seed Health Testing Methods for Detecting Fungi, 2nd Edition. **International Seed Testing Association. Switzerland**
30. Morse S., M. Acholo, N. McNamara and R. Oliver (2000). Control of storage insects as a means of limiting yam tuber fungal rots. **J. Stored Products Res.** **36**: 37-45
31. Nakamura C.V., T. Ueda-Nakamura, E. Bando, A.F. Melo, D.A. Cortez and B.P. Dias Filho (1999). Antibacterial Activity of *Ocimum gratissimum* L. Essential Oil. **Mem. Inst. Oswaldo Cruz**, **94**. 675-678 pp.
32. Noon P.A. (1978). Storage and Market diseases of Yams. **Trop. Sci.** **20**. pp 17-81
33. Norman M.J.T., Pearson C.J., Searle P.G.E. (1995). Tropical Food Crops in their environment 2nd Edition. **Cambridge Univ. press, U.K.** pp. 305- 316.
34. Nwachukwu E.O. and J.O. Osuji (2008). Evaluation of plant extracts for antifungal activity against *Sclerotium rolfsii* causing cocoyam cormel rot in storage. Department of Plant Science & Biotechnology, University of Port Harcourt. **Research Journal of Agriculture and Biological Sciences**, **4(6)**: 784
35. Nwakiti O.A. and O.B. Arene (1987). Diseases of yam in Nigeria. **Pest Articles and News Summaries (PANS)** **24**: 468.

36. Ogundana S.K., S.H.Z. Naqvi and J.A. Ekundayo (1970). Fungi associated with soft rot of yams in storage in Nigeria. **Trans. Br. Mycol. Soc.** Pp 54
37. Okigbo R.N. and I.A. Nmeka (2005). Control of yam tuber rot with leaf extracts of *Xylopiya aethiopica* and *Zingiber officinale*. **Department Of Microbiology, Michael Okpara University of Agriculture, Umudike.** 806 pp.
38. Okigbo R.N. and A.O. Emoghene (2004). Antifungal activity of leaf extracts of some plant species on *Mycosphaerella fijiensis* Morelet, the causal organism of black sigatoka disease in banana (*Musa acuminata*). **KMITL Sci. J.** **4(1):** 20-31pp
39. Okigbo R.N. and U.O. Ogbonnaya (2006). Antifungal effects of two tropical plant extracts (*Ocimum gratissimum* and *Aframomum melegueta*) on post-harvest yam rot. **African Journal of Biotechnology Vol. 5(9).** 727-731 pp
40. Okigbo R.N. and F.E.O. Ikediugwu (2002). Evaluation of water losses in different regions of yam (*Dioscorea* spp.) tuber in storage. **Nig. J. Exp. Appl Bio** **3.** 320 pp
41. Okigbo R.N. and F.E.O. Ikediugwu (2000). Studies on biological control of postharvest rot of yam with *Trichoderma viride*. **J. Phytopathol.** **148:** 351-355.
42. Osagie A.U. (1992). The yam tuber in storage. **Postharvest Research Unit. Ambik Press.** 11- 18pp.
43. Peters J. (2000). Control of yam diseases in forest margin farming systems in Ghana. **University of Reading.** (In 2000–01: DNA fingerprinting of experimental yams to be completed. Nematology thesis to be examined).
44. Pursglove J.W. (1989). Tropical Crops Monocotyledons. **Longmans London.**

607pp

45. SinoHarves (2005). Mancozeb ([www.sinoharvest.com/products/Mancozeb.shtml](http://www.sinoharvest.com/products/Mancozeb.shtml), date accessed: 10-03-2008)
46. Tetteh J.P. and C. Saakwa (1994). Prospects and constraints of yam production in Ghana. In proceedings of 9<sup>th</sup> symposium of the International Society for Tropical Root Crops. Ofori and Halm. **Accra, Ghana**. 20-26 pp.
47. Twumasi J.K. (1984). Fungi associated with tar spot disease of water yam in Ghana. **Ghana Journal of Agricultural Science**. 14-19: 115-116
48. Undie A.S. and P.I. Akubue (1986). Pharmacological evaluation of *Dioscorea dumetorum* tuber used in traditional antidiabetic therapy. **J. Ethnopharmacol.** 15: 133-14
49. Vinayaka H., M.L. Jeeva, S. Edison (2009). Yam Diseases: Ecology and Management. **Central Tuber Crops Research Institute, Kerala, India** (In: Encyclopedia of Pest Management, date accessed: 28-01-10).

## APPENDICES

### Appendix 1:

#### SURVEY ON YAM PRODUCTION, THEIR CONSTRAINTS AND YAM ROT DISEASE AT MAJOR YAM PRODUCING AREAS IN GHANA

Name..... Age.....

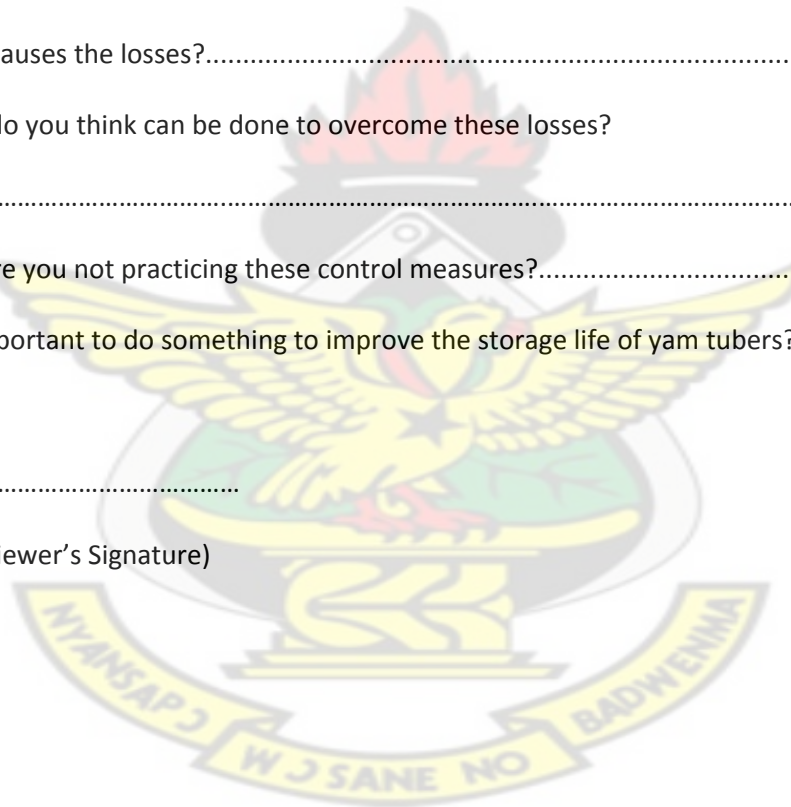
Community..... District.....

Region..... Date.....

1. How long have you been farming?.....
2. What is your level of education?.....
3. What crops do you cultivate?.....
4. Among these crops, which ones are your major crops?.....
5. Which of them helps you to achieve food security?.....
6. What is the land size of the major crop?.....
7. What are the major constraints facing you in farming?  
.....  
.....  
.....
8. What varieties of yam do you cultivate?.....
9. Which yam diseases do you know?.....
10. Do these diseases have an effect on the yield?.....
11. If yes, what effect?.....
12. What quantity of the yield is affected by the diseases?.....
13. In monetary terms, how much do you lose?.....
14. Do you store the yam tubers after harvest?.....

15. If yes, what method(s) do you practice? .....
16. Is this the only method you know?.....
17. If no, then why have adopted this storage method?  
.....
18. How long does it take you to store your tubers?.....
19. Have you tried the use of chemical for treating yam tubers prior to storage before?.....
20. Do you lose some of your yams in storage?.....
21. If yes, what percentage of your stored tubers do you lose?.....
22. What causes the losses?.....
23. What do you think can be done to overcome these losses?  
.....
24. Why are you not practicing these control measures?.....
25. Is it important to do something to improve the storage life of yam tubers?.....

.....  
(Interviewer's Signature)



Appendix 2: Tuber rot of white yam ('Dente') tubers after 14 weeks of storage at Ejura.

| Replications | Treatment            |                     |                       |                     |                      |                     |
|--------------|----------------------|---------------------|-----------------------|---------------------|----------------------|---------------------|
|              | Shavit WP            |                     | Mancozeb Metalaxyl WP |                     | Control              |                     |
|              | No. of rotten tubers | No. of clean tubers | No. of rotten tubers  | No. of clean tubers | No. of rotten tubers | No. of clean tubers |
| <b>R1</b>    | 2                    | 13                  | 6                     | 9                   | 8                    | 7                   |
| <b>R2</b>    | 3                    | 12                  | 5                     | 10                  | 9                    | 6                   |
| <b>R3</b>    | 2                    | 13                  | 2                     | 13                  | 7                    | 8                   |
| <b>TOTAL</b> | 7                    | 38                  | 13                    | 32                  | 24                   | 21                  |
| <b>%</b>     | <b>15.55</b>         | <b>84.45</b>        | <b>28.89</b>          | <b>71.11</b>        | <b>53.33</b>         | <b>46.67</b>        |

Appendix 3: Tuber rot of white yam ('pona') tubers after 14 weeks of storage at Amponsakrom (Wenchi).

| Replications | Treatment            |                     |                       |                     |                      |                     |
|--------------|----------------------|---------------------|-----------------------|---------------------|----------------------|---------------------|
|              | Shavit WP            |                     | Mancozeb Metalaxyl WP |                     | Control              |                     |
|              | No. of rotten tubers | No. of clean tubers | No. of rotten tubers  | No. of clean tubers | No. of rotten tubers | No. of clean tubers |
| <b>R1</b>    | 0                    | 15                  | 0                     | 15                  | 0                    | 15                  |
| <b>R2</b>    | 3                    | 12                  | 0                     | 15                  | 0                    | 15                  |
| <b>R3</b>    | 0                    | 15                  | 4                     | 11                  | 10                   | 5                   |
| <b>TOTAL</b> | 3                    | 42                  | 4                     | 41                  | 10                   | 35                  |
| <b>%</b>     | <b>6.67</b>          | <b>93.33</b>        | <b>8.89</b>           | <b>91.11</b>        | <b>22.22</b>         | <b>77.78</b>        |