

**"ROTTING OF COCOYAM [*XANTHOSOMA*  
*SAGITTIFOLIUM* (L.) SCHOTT] CORMELS IN STORAGE:  
AETIOLOGY AND CONTROL"**

BY



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## DECLARATION

I declare that the work embodied in this thesis represents my original work and has not been submitted to another University for the award of a degree.

Any assistance received in the course of writing this thesis has been duly acknowledged.



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## DEDICATION

To the Glory of God and to Rev. and Mrs. Obiri Annor of Achimota School



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## ABSTRACT

A survey was carried out in November, 1997 in Accra to obtain basic information on the post-harvest handling and deterioration of cocoyam cormels from retailers and consumers. Studies were also undertaken between December, 1997 and July, 1998 to identify the pathogens responsible for rots in cocoyam cormels, to investigate the influence of variety and the presence of 'natural wounds' on the rotting of cocoyam cormels and to assess the efficacy of thiabendazole and lime in controlling cocoyam rots in storage.

The survey revealed that there are three varieties of cocoyam available on the markets and of these the pink variety (Amankanipa) is the commonest and most preferred. It was also apparent that cocoyam for sale in Accra is obtained mainly through middlemen and that these come mostly from the Eastern Region of Ghana. Cocoyam supplies to markets in Accra are done in bits and these take up to one week to be disposed of. Cocoyam cormel rots encountered by respondents is therefore low (0 - 5%). No measures are taken by respondents to control rots in cocoyam.

Isolations made from 123 partially-rotten cormels obtained from markets in Accra and a storage barn revealed that storage rots in cocoyam are caused by *Aspergillus flavus* (2.4%), *Botryodiplodia theobromae* (12.2%), *Fusarium oxysporum* (31.7%), *Fusarium solani* (45.5%), *Penicillium citrinum* (4.9%), and *Rhizopus stolonifer* (3.3%).

A consistently higher weight loss was associated with Amankanipa (21.27%) compared with Amankanifitaa (20.28%) and Amankani Serwa (20.97%) varieties after 16 weeks of storage. This was, however, significant only in the first two weeks of storage. On the other hand, the Amankanifitaa and Amankani Serwa varieties recorded significantly higher percent sprouts (17.50% and 12.50% respectively) than the Amankanipa variety (1.25%). Incidence of rots was highest in the Amankanifitaa variety followed by Amankani Serwa and then Amankanipa variety reaching their respective peaks at 90.0%, 75.0% and 76.3% after a 16-week storage period.

The 'natural' wounds at the proximal ends of cormels were the dominant infection courts for rot-causing pathogens. Control was, therefore, targeted at this point. Both thiabendazole and lime were observed to be effective in checking the growth of the rot-causing fungi *in vitro*. Thiabendazole was observed to perform better in reducing the incidence and spread of rots in cocoyam during the first six weeks of storage.



## CHAPTER ONE

### INTRODUCTION

Cocoyam (*Xanthosoma sagittifolium* (L.) Schott) is an important root crop in tropical and sub-tropical areas mainly in the Pacific and Caribbean islands and in West Africa (Plucknett *et al.*, 1970). It provides food energy for about 200 million people in the tropics (Wutoh *et al.*, 1994) and is a staple in certain parts of some African countries (Lyonga, 1979; Karikari, 1984). The food-energy yield of cocoyam per unit land area is higher than most root crops and has relatively few diseases and pests problems (Onwueme, 1978; IITA, 1982).

According to the Food and Agriculture Organisation (F.A.O.) of the United Nations, in 1988 the total world cocoyam production was estimated at  $5.5 \times 10^6$  tonnes with more than half of that production ( $3.4 \times 10^6$  tonnes) from Africa. Nigeria is the world's largest producer of cocoyam ( $1.8 \times 10^6$  tonnes) followed by Ghana ( $0.65 \times 10^6$  tonnes).

In spite of these, very little information is available on cocoyam. The few work has focused on production leaving investigations on its post-harvest losses largely marginalised (Booth, 1974). Storage losses in cocoyam have been identified as a major factor limiting the quantity and quality of the crop available for human consumption. The need to carry out a survey aimed at obtaining

information on storage conditions of cocoyam is, therefore, necessary. There is also the need for a study of the factors responsible for storage losses in cocoyam.

Storage losses in cocoyam are known to result from weight loss, sprouting and microbial decay. Until recently, no information was available on pathogens associated with cocoyam rots in Ghana. Ampomah (1997), in an under-graduate project, isolated *Aspergillus* sp., *Botryodiplodia theobromae*, *Fusarium* sp., *Rhizopus* sp. and *Penicillium* sp. as pathogens causing rots in cocoyam in Ghana. This work needs to be repeated to confirm the results, expanded to include new areas that were not studied and methodology improved upon, where necessary.

Onwueme (1978) and work done at IITA (1982) indicate that cocoyam cormels matures for harvesting 9 – 12 months after planting. They, however, reported that no serious deterioration occurs if the crop is left in the ground for a few weeks after maturity and harvested as needed. Even though this practice provides field storage for the crop it, no doubt, discourages the commercial production of the crop as it places undue restriction on the availability of land. There is therefore the need for an in-depth study into factors that influence storage rots of cocoyam cormels and how these could be controlled.

Current research efforts indicate that resistance of cocoyam to storage losses is influenced by variety (Bikomo, 1991). Wright (1940) and Karikari (1971) have identified and described cocoyam varieties in Ghana including Amankanipa, Amankanifitaa and Amankani Serwa. Identification of variety(ies) with superior shelf life for greater research attention is, therefore, useful.

The process of harvesting cocoyam involves the detachment of cormels from mother corms. This creates 'natural' wounds at the proximal ends of the cormels. The role of these wounds as entry points for rot-causing organisms needs to be ascertained as a useful aid to designing an appropriate control strategy.

A number of chemicals, including thiabendazole (a benzimidazole derivative) and lime paste (slaked lime), have been used in checking post-harvest spoilage of roots and tubers with varying degrees of success (Burden, 1969; Thompson *et al.*, 1977; Cornelius, 1998). Their efficacy in controlling rots in cocoyam in Ghana, however, has not been explored.

The objectives of this study, therefore, were;

- a) to obtain, through a survey, information on cocoyam varieties available in Ghana, major producing areas, methods of storage, storage problems and their control from cocoyam retailers and consumers in Accra
- b) to isolate and identify the pathogens associated with the rotting of cocoyam cormels
- c) to investigate the influence of variety as well as the presence of 'natural' wounds on rotting of cocoyam cormels and

- d) to assess the efficacy of thiabendazole and lime in controlling cocoyam rots in storage.

## CHAPTER TWO

### LITERATURE REVIEW

#### 2.1. Origin, botany and classification of cocoyam

##### 2.1.1. Origin

Cocoyam is reported to have originated in tropical America and was in cultivation in pre-Colombian times. It was introduced into West Africa by West Indian Missionaries during the 1840s (Wright, 1930; Karikari, 1971; Purseglove, 1972; Doku, 1980). In Ghana, it was first planted at Akropong-Akwapim in the garden of Moore from where it gradually spread through the forest belt following the cultivation of cocoa; for whose seedlings the cocoyam provided ideal shade (Karikari, 1971).

##### 2.1.2. Botany

Even though variability exists in the morphological characters of this species of cocoyam, it is basically a herbaceous perennial. The shoot consists mainly of leaves, which arise, in a whorl from the apex of the corm. The terminal bud remains very close to this apex. The leaf lamina is more or less heart-shaped with a deep indentation dividing the lamina into two lobes (IITA, 1982).

The inflorescence of cocoyam is a spadix subtended by a spathe, which is pale-green in colour. The spadix is cylindrical and about 15 cm long. The female

flowers occur at the base of the spadix, the male flowers towards the tip and sterile flowers in between these two regions.

Cormels arise from axillary buds present on the corm. Morphologically, cormels represent the lateral branches of the plant stem, while the corm represents the main stem. Each cormel is a fleshy, tapering structure being relatively thin at its point of attachment to the corm becoming fatter and rounded towards the distal end (Onwueme, 1978; F.A.O., 1994).

### 2.1.3. Classification

Cocoyam belongs to the genus *Xanthosoma*, which is also a member of the family Araceae. As with other vegetatively-propagated crops, variability within *Xanthosoma* is fairly large. They include crops popularly known as *yautia*, *tannia*, *macabo*, *mafaffa* or 'new cocoyam'.

Many species have been identified based mainly on vegetative characteristics (Haudricourt, 1941). These include *X. sagittifolium*, *X. jacquini*, *X. caracu*, *X. mafaffa*, *X. atrovirens*, *X. belophyllum* and *X. brasiliense*. However, there is general agreement that the most widely-cultivated species is *X. sagittifolium*. This species itself has numerous variability in terms of maturity period, cormel texture, taste, colour, size and utilisation of leaves (Coursey, 1968; Onwueme, 1978; Doku, 1980)

#### 2.1.4. Cocoyam varieties in Ghana

The number of varieties of the 'new cocoyam' (*Xanthosoma*) introduced into Ghana is not actually known. Whereas Wright (1930) reported four varieties, Karikari (1971) identified two other varieties in addition namely;

- i) 'Amankanipa' or 'Amankani kokoo': This is a large plant, 6-8 feet high. Leaf sagittate, dark-green, lighter on the under surface with prominent venation. Petiole reddish-purple, cormel flesh and skin pinkish with flesh producing a pink latex when freshly cut through. It may flower in wetter districts. This is the commonest variety and is said to possess all the desirable properties of cooking, texture and taste.
- ii) 'Amankani fufuo': Very similar to 'Amankanipa'. Except that leaves are not quite so dark with pale-purple petiole and white cormels.
- iii) 'Amankanifitaa': Above-ground parts resemble 'Amankani fufuo' but the plant is much more delicate. Cormels are white with one or several constrictions. The plant is smaller than in the above two varieties.
- iv) 'Amankani Antwibo': Similar to 'Amankanifitaa' but with very pale-green petioles and pink unstricted cormels. Both the central stem and the cormels of this variety are edible.

- v) 'Amankani Serwa': This resembles the 'Amankanifitaa' variety except that the cormels are very white and the skin is very thin. It is difficult to peel and is usually cooked together with the skin. After cooking, the skin splits and becomes peelable.
- vi) 'Amankani kyirepe': This cocoyam resembles the 'Antwibo' variety. It is, however, rich in sugar and is therefore used in sweetening foods. It contains some poisonous properties and therefore needs to be boiled for about 12 hours before being eaten.

Each of these varieties has a name in the dialect of the locality where it occurs, and is descriptive of a striking characteristic or a peculiar quality it may possess. The same variety, therefore, could acquire as many names as there are different characters (Karikari, 1971). Based on cormel flesh and skin colour, however, cocoyam is simply referred to as either 'pink' or 'white' as precise identification is difficult without reference to the above-ground parts. In Cameroon, however, three varieties of cocoyam have been identified based on cormel flesh and skin colour. These are the pink, white and yellow (Numfor and Lyonga, 1986).

## 2.2. Sources and magnitude of storage losses in cocoyam

Post-harvest losses in cocoyam manifest in loss of quantity or quality of the produce or both. These losses result from mechanical, physiological or pathological factors or various combinations of all three (Booth, 1974).

### 2.2.1. Mechanical injury

Mechanical injury takes many forms and occurs at all stages in the production cycle from the pre-harvest operations through harvesting and handling operations such as grading, packing and transportation, to exposure in the market and finally in the home.

In addition to causing such direct losses, mechanically-damaged produce are also exposed to increased physiological losses and allows the entry of destructive micro-organisms. Mechanically injured produce will normally deteriorate rapidly and should never be used for long-term storage (Coursey and Booth, 1972; Booth, 1974).

### 2.2.2. Physiological factors

Physiological factors that influence the storage life of cocoyam are the result of transpiratory losses of water, respiratory losses and losses due to sprouting.

Transpiration leads to dehydration of cocoyam cormels in storage the resulting in a reduction in the cormel fresh weight without affecting dry matter (Booth, 1974). The rate of moisture loss has been found to vary with the seasons.

In the dry season, large losses of water is expected especially in material of such high moisture content (Coursey, 1967). Cormel transpiration has also been reported to depend on the permeability of the periderm, which, in turn, is a function of the maturity of the crop. Burton (1982) reported that immature cormels recorded sharp decreases in their moisture content. He attributed this to their thinner and more permeable periderm, compared to the thicker periderm in mature crops.

Coursey and Russell (1969) have shown that very substantial weight losses are due to respiration. Respiratory processes result in the conversion of part of the carbohydrate of the cormels into carbon dioxide and water which are lost to the air. They further reported that with yam tubers, respiratory activity accounts for 30% of the weight loss (Coursey and Russell, 1969). Coursey (1967) reported measurements of respiratory losses of 100 mg CO<sub>2</sub>/kg per hour even at 20<sup>0</sup>C. This figure, he reported, corresponds to a dry matter loss of about 7.5% per month.

Little information is available on the respiration of cocoyam cormels. Bikomo (1991) reported that for the same maturity phase, weight loss was least in white cocoyam but greatest in pink cocoyam and that weight loss was remarkably high among cormels harvested eight to nine months after planting. Such high weight loss from younger cormels, he suggested, may result from intensive respiration and transpiration of immature tissue.

Another aspect of respiratory losses is sprouting which is the result of variation in the chemical composition of cormels. This mainly affects the glucose content and seems to occur after opening of the buds, when there is a mobilisation

of reserves for synthesis of the shoots leading to sprouting (Chisman and Fiagan, 1986). Sprouting in cocoyam cormels occurs after breaking of dormancy - a period during which satisfactory storage of the produce is no longer possible. It is reported that when sprouting occurs, over 50 percent loss is observed after two months and 95% after five months (NAS, 1978).

Sprouting has also been reported to vary among varieties as well as maturity of cormels at harvest. Bikomo (1991) observed that for cormels harvested at 10 - 11 months after planting, white cocoyam exhibited a stronger tendency to produce sprouts than the pink variety of cocoyam. This has been attributed to the rapid physiological maturation of the white variety of cocoyam and the lack of effective stimulation by specific growth inhibitors. Bikomo (1991) also reported that for both pink and white varieties of cocoyam sprouting was less among cormels harvested at eight to nine months after planting compared to those harvested at 10 - 11 months after planting.

### 2.2.3. Pathological losses

Attack by micro-organisms is probably the most serious cause of post-harvest loss in cocoyam. Pathogenic losses may, in general, be divided into those reducing the quantity of sound produce and those reducing the quality of produce (Booth, 1974).

Quantitative pathogenic losses result from the rapid and extensive breakdown of host tissues by micro-organisms. The pattern of attack is normally an initial infection, normally through a wound, by one or a few specific pathogens.

This is followed by a massive infection by a broad spectrum of weakly pathogenic or saprophytic organisms which grow on the dead or moribund tissue remaining from the primary infections (Tomkins, 1951; Turner, 1959).

Qualitative pathogenic losses are typically the result of blemish or surface diseases that render the produce less attractive and less marketable even though little actual damage of tissue has occurred.

The occurrence and magnitude of losses due to rot has been reported by many workers with various degrees of variability. Serious rotting of the crop during storage is common and a large quantity is lost as a result. Baybay (1922), during storage experiments in the Philippines, reported a minimum of 30% cormel waste after three months' storage. In Cameroon, Praquin and Michel (1971) recorded total corm losses of 50% and 95% after two and five months' storage respectively. In Nigeria, loss of 40 - 50 percent cormels due to rot was recorded by the National Root Crops Research Institute (NRCRI, 1980). Ogali (1994) reported 31.6 and 35.7 percent loss after 16 and 24 weeks' storage respectively. Bikomo (1991) has shown that the stage of maturity of cormels influences the visual quality. He reported that harvesting cormels after 10 - 11 months after planting improved their overall storage quality with longer-lasting freshness and firmness.

Rots of stored cocoyam cormels have been found to start mostly from wounds arising from the points of detachment from the mother corms, harvest bruises or other injuries. Of 1652 cases of rot which were observed at the early stage of decay, 62.2% originated from the proximal ends (point of detachment

from mother corms), 30.2% from surface wounds, 4.9% from the tops and 0.9% from nematode galls (Maduewesi and Onyike, 1980).

Generally, rots are of two main types - dry rots and wet rots (Maduewesi and Onyike, 1980). Wright (1940), however, described three different types of rots of *Xanthosoma sagittifolium* - dry rot, spongy black rot and sclerotium rot. Okeke (1980) reported that rots incited by *Botryodiplodia theobromae* were pale and soft but as the disease progressed, the colour changed and the tissues turned dark-brown. Infected tissues later became spongy-black, producing a putrefying odour. He also observed that cocoyam rots caused by the two species of *Fusarium* (*F. solani* and *F. moniliforme*) were generally soft but, at the early stages, the cream-dirty-white rot caused by *F. moniliforme* was easily distinguished from the bluish-grey soft rot caused by *F. solani*. Brown rotting of cocoyam corms and cormels was caused by *Sclerotium rolfsii*.

### 2.3. Pathogens responsible for causing rots in cocoyam

Evidence from available literature seems to suggest that microbial decay in cocoyam is predominantly of fungal etiology, even though a few bacteria species have also been reported. Pathogens reported as being responsible for causing rots in cocoyam and their sources are presented in Table 1.

**Table 1.** Pathogens responsible for causing rots in cocoyam, their basic characteristics and literature sources.

Organism	Basic characteristics	Source
<i>Fusarium solani</i>	Mycelium cottony on PDA; macro-conidia stocky with thick parallel walls and blunt ends; spore masses cream, yellow, often infiltrated by blue; micro-conidia usually abundant, ovoid or oblong 0-1 septate formed from elongated conidiophores; chlamydo spores present.	Harter (1916); Mosalaem (1959); Gollifer and Booth (1973b); Ogundana (1976); Maduewesi and Onyike (1980); Samson and van Reenen-Hoekstra (1988); Ogali (1994)
<i>Fusarium moniliforme</i>	Macro-conidia scarce with thin-walled, narrow, rectangular cells; micro-conidia abundant and borne in chains; chlamydo spores absent	Mosalaem (1959); Ogundana (1976); Okeke (1980); Ogali (1994)
<i>Fusarium oxysporum</i>	Aerial mycelium sparse; macro-conidia fine, elongated with thin walls; micro-conidia septate borne on phialides on short much-branched conidiophores;	Mosalaem (1959); Gollifer and Booth (1973a); Samson and van Reenen-

	chlamydo-spores present.	Hoekstra (1988)
<i>Botryodiplodia</i> <i>theobromae</i>	Mycelium cottony and gray initially turning dark later; pycnidia black; conidiophores simple, short; conidia hyaline and one-celled when immature turning dark-brown and 2-celled when mature.	D'Souza and Moniz (1968); Barnet and Hunter (1972); Coursey and Booth (1972); Gollifer and Booth (1973b); Maduewesi and Onyike (1980); Okeke (1980); Ogali (1994)
<i>Sclerotium</i> <i>rolfsii</i> ( <i>Corticium</i> <i>rolfsii</i> )	Asexual fruiting bodies lacking; sclerotia brown to black, globose or irregular, compact; mycelium usually light	Harter (1916); Barnet and Hunter (1972); Gollifer and Booth (1973b); Ogundana (1976); Maduewesi and Onyike (1980); Okeke (1980)
<i>Rhizopus</i> <i>stolonifer</i>	Colony whitish becoming grayish-brown due to brownish sporangiophores and brown-black sporangia; sporangia globose,	Maduewesi and Onyike (1980); Samson and van

	blackish-brown at maturity; columella globose, subglobose, ovoid; sporangiospores irregular in shape	Reenen-Hoekstra (1988)
<i>Penicillium citrinum</i>	Colonies grow restrictedly consisting of a dense felt of conidiophores blue-green in colour; reverse colony normally yellow to orange; conidiophores biverticillate and smooth-walled; conidia produced in columns, globose to subglobose	Samson and van Reenen-Hoekstra (1988);Ogali (1994)
<i>Aspergillus niger</i>	Colony consists of a compact white or yellow basal felt; conidial heads radiate, tending to split into loose columns with age; conidiophores smooth-walled, hyaline but often in brown colours; vesicles globose to subglobose; phialides borne on metulae; conidia globose to subglobose.	Samson and van Reenen-Hoekstra (1988);Ogali (1994)
<i>Cladosporium herbarum</i>	Colony velvety, locally powdery due to conidia; conidiophores mostly arising laterally sometimes terminally from the hyphae with terminal and intercalary swellings; conidia in long, often branched chains, ellipsoidal to cylindrical with	Barnet and Hunter (1972);Ogali (1994)

	rounded ends.	
<i>Diplodia</i> sp.	Pycnidia black, simple, globose; conidiophores slender, simple; conidia dark, 2-celled.	Harter (1916); Barnet and Hunter (1972)
<i>Pythium</i> spp.	Formation of zoospores within a vesicle at the open tip of the discharge tube of the filamentous sporangium; sexual reproduction by oogonium and antheridium.	Bessey (1971); Coursey and Booth (1972); Jackson and Gollifer (1975)
<i>Rhizoctonia</i> spp.	Mycelium brown with long cells, septa of branch set off from main hypha; sclerotia brown or black frequently small and loosely formed among and connected by mycelial threads.	Burton (1970); Barnet and Hunter (1972); Coursey and Booth (1972)
<i>Phytophthora colocasiae</i>	Aerial filament in moist air producing sympodially a succession of sporangia; formation of zoospores within sporangia and emission into a vesicle.	Bessey (1971); Jackson and Gollifer (1975)
<i>Trichoderma harmatum</i>	Colony growing rapidly initially hyaline, later usually in green shades due to conidium production; conidiophores in tufts, repeatedly branched bearing clusters	Barnet and Hunter (1972); Ogundana (1976)

of flask-shaped phialides; conidia in slimy conidial heads, sometimes hyaline, often green, smooth or rough-walled;  
 - chlamydospores present in most species, intercalary or sometimes terminal on short side branches of the hyphae

<i>Botrytis</i> sp.	Colony broadly spreading, hyaline at first becoming light-gray to dark-brown; conidiophores long, slender, hyaline or pigmented sometimes dichotomous near apex; conidia borne on clusters on short sterigmata; conidia hyaline or ash-coloured one-celled, ovoid; black irregular sclerotia usually produced.	Burton (1970); Barnet and Hunter (1972); Coursey and Booth (1972); Samson and van Reenen-Hoekstra (1988)
<i>Erwinia carotovora</i>	Rod-shaped (0.7x1.0-2.0 $\mu$ ); motile by means of 1-6 peritrichous flagella; facultatively-anaerobic; no capsules present; Gram-negative; liquefies gelatin; coagulates litmus milk in 4 days	Harter (1916); Breed <i>et al.</i> (1957); Coursey and Booth (1972)
<i>E. chrysanthemi</i>	Rod-shaped (0.7x2.1 $\mu$ ); occurs singly and in pairs; facultatively-anaerobic; motile by means of a varying number of peritrichous	Breed <i>et al.</i> (1957); Bikomot and Brecht (1989)

flagella; Gram-negative; liquefies gelatin;

becomes lavender in 2-3 days.

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In Ghana, no available record existed on the pathogens causing cocoyam rots until Ampomah (1997) isolated *Aspergillus* sp., *Botryodiplodia theobromae*, *Fusarium* sp., *Penicillium* sp. and *Rhizopus* sp.

Fresh cocoyams are not usually palatable to insects or rodents. Therefore, animals are not a major problem to fresh cocoyam storage (Numfor and Lyonga, 1986).

#### 2.4. Control of storage rots of cocoyam

At each potential loss stage, in relation to the nature of the various causes and agents, it is necessary to use specific loss-prevention and control technologies. To be effective, post-harvest technologies must, as much as possible, take into account both the exogenous and endogenous factors that may cause losses.

##### 2.4.1. The use of pesticides

A wide range of chemicals have been used in reducing post-harvest spoilage of root and tuber crops. Successful chemical treatment depends upon the use of compounds which are either fungistatic or fungicidal at dosage rates that are not phytotoxic (Booth, 1974).

In an experiment to assess the effect of borax, copper fungicide and limewash in reducing storage losses in yams, Coursey (1961) reported that

treatments exerted some protective effect up to 10 - 12 weeks' storage but the effect was not felt thereafter. He found out that limewash was the most effective fungicidal treatment in reducing storage losses, being significantly better than the others.

Thompson *et al.* (1977) studied the effect of thiabendazole, benomyl, dicloran diphenyl impregnated paper and lime on storage losses of yam. They reported that thiabendazole and benomyl at 1000 ppm gave good control and greatly reduced storage losses and that lime-coated tubers were unsuitable for marketing as a result of appearance. Eckert and Kolbenzen (1964) and Scott and Roberts (1967) have reported that thiabendazole at concentration as low as 140 ppm has been shown to be effective against black end rot in bananas. Thiabendazole at 1000 ppm also gave good control and greatly reduced storage losses in yam tubers in cold storage.

The use of fungicidal treatments in the control of rots in cocoyam has been rather sparse. In a study to evaluate the impact of chlorine dips on the storage of cocoyam, Bikomo (1991) observed that cormels treated with one percent sodium hypochlorite (NaOCl) solution significantly improved shelf life. In Nigeria, work done by Ogali (1994) showed that treatment of cocoyam cormels with wood-ash was beneficial when stored in perforated polythene bags.

While the use of broad spectrum systemic fungicides with very low toxicity holds promise for the future, little commercial use has been made of them in the tropics. Often these chemicals are expensive with cumbersome application techniques. It is in apparent regard to these limitations that many workers have



recommended the manipulation of storage environments through such techniques as curing and packaging to reduce losses.

#### 2.4.2. Curing

One of the most effective and simple means of reducing post-harvest dehydration and pathological losses of several root crops is by curing. Curing is a wound-healing process during which general skin strengthening also occurs. The process is stimulated by conditions of relatively high temperatures and humidities and involves suberisation followed by the development of a wound periderm that is effective in retarding water loss and acts as a barrier against infection (Booth, 1974).

The merits of curing for reducing post-harvest losses in potatoes (Burton, 1966; Booth and Proctor, 1972), sweet potatoes (Kushman and Wright, 1969) and recently in yam (Gonzalez and Collazo de Rivera, 1972) have been reported. The effect of the practice on cocoyam storage, however, has been rather disappointing. Bikomot and Brecht (1989) reported that even though tissue sections from cured and uncured cormels showed the presence of cork cells and the formation of a thickened periderm layer in the cured cormels, curing did not reduce the incidence or severity of decay. The result of that study is inherently questionable. For, while curing may be effective in checking microbial entry on the lateral side of cormels usually protected by the periderm, it would have little or no effect on the 'natural' wound created at the proximal ends of cormels during harvesting. Therefore the

source of infection needs to be ascertained before firm conclusions could be drawn.

#### 2.4.3. Packaging

Studies have been conducted by many workers to show the influence of packaging on the storability of cocoyam cormels. In evaluating the effect of burlap bags, perforated plastic bags and a high density film on the storability of cocoyam cormels, Bikomot and Brecht (1989) found that packaging may not be needed for cocoyam destined for short storage before consumption as undamaged cormels can tolerate short exposure to ambient conditions. However, packaging facilitates the prolonged transportation and handling of cocoyam cormels. For prolonged storage, they reported that perforated plastic and burlap bags delay spoilage of cormels as adequate ventilation or the avoidance of anaerobic conditions and excess humidity limit pathogen growth and sprouting and assures good storage.

Bikomo (1991) stored cocoyam cormels in jute sacks and perforated plastic bags and observed that perforated plastic bags significantly reduced weight loss in cormels compared to the unpacked and those stored in jute sacks. He intimated that water absorption from the cormels was particularly accentuated in the vicinity of the jute sacks.

In Nigeria, Ogali (1994) reported that cormels stored in perforated plastic bags were found to have reduced weight loss. He attributed this to the higher relative humidity maintained inside the polythene bags.

#### 2.4.4. Temperature and humidity regulation

Cocoyam is said to be stored in cool, dry, well-ventilated surroundings (Onwueme, 1978). Onwueme (1978) further reported that the best temperature for prolonged storage is about 7°C and that storage at higher temperatures is not satisfactory for long periods while storage at lower, non-freezing temperatures results in death of the buds and decay of the cormels within two months.

The effect of humidity on cormel rot has been found to vary with the pathogen involved. Ogundana (1976), working with *Xanthosoma sagittifolium* observed that cormel rot was reduced when they were stored below 50% relative humidity. This finding agrees with observations on *Colocasia esculenta* by Gollifer and Booth (1973a) who worked primarily with *Fusarium moniliforme* and *Botryodiplodia theobromae*. These two pathogens, they reported, are characterised by production of spores that require high humidity for dispersal, germination and penetration of the host. It is plausible that rot induced by these pathogens increase with increase in relative humidity. *Corticium rolfsii* (perfect stage of *Sclerotium rolfsii*), however, requires low humidity for germination (Watkins, 1958). Low humidities result in wrinkling and cracking of the sclerotial cortex. Such fungi are known to grow better under conditions of low relative humidity. In general, rots in *X. sagittifolium* have been reported to increase with increases in humidity (Arene and Okpala, 1980).



#### 2.4.5. Traditional control methods

Unlike yam, which is normally harvested immediately after maturity, cocoyam may be left in the ground after maturity and harvested as needed (Onwueme, 1978). Attempts have, however, been made in several countries to preserve cocoyam in its natural condition until consumption.

In a survey conducted in Nigeria, Knipscheer and Wilson (1980) showed that the predominance of household consumption and the possibility of leaving cocoyam in the ground means that elaborate storage facilities are not required. They reported, however, that the storage of cocoyam in barns and in the house (in baskets) is not uncommon. Coconut husk, if maintained at a damp but not wet condition, and used to line baskets offers satisfactory storage for cocoyam (Passam, 1982).

Arene and Okpala (1980) have reported that cormel rot in *X. sagittifolium* is reduced when cormels are stored on raised rafters and left uncovered. This technique, they intimated, creates an unfavourable micro-climate of high humidity on the surface of the cormels and the freer aeration speeds up subsequent hardening of the cormels' flesh against invasion. In Ghana, Nyanteng (1972) reported that the crop is generally stored in soil pits, on rafters or heaped on barn floors and covered with dry banana or plantain leaves.

## CHAPTER THREE

### MATERIALS AND METHODS

#### 3.1. Survey methodology

The survey was carried out in four markets in Accra to obtain information from retailers and consumers on the varieties of cocoyam commonly available in Ghana, major producing areas, methods of storage, extent of rot diseases and traditional control measures.

Questionnaires (Appendices 1 & 2) were designed, pre-tested and administered in November, 1997 to 12 cocoyam retailers each in Agboghloshie and Mallam Atta markets, 10 retailers in Kaneshie market, and eight retailers in Madina market all in Accra and 20 consumers selected at random in Accra.

#### 3.2. Isolation and identification of micro-organisms responsible for rots in cocoyam and proof of pathogenicity

Partially decayed cocoyam cormels were used for the isolation of micro-organisms. These were obtained from two sources namely i) the four markets in Accra where survey was carried out and ii) storage barn at the Sinna's garden of the Crop Science Department, University of Ghana where cormels were kept for shelf life studies. In all, 123 partially decayed cormels were used for isolation.

Small sections of cocoyam tissue from the advancing margin of rot and adjoining healthy tissue were surface sterilised in 1% sodium hypochlorite (NaOCl) solution for two minutes. They were blotted dry on filter paper and plated on 2% Oxoid water agar (WA) plates. The plates were then enclosed in clean polyethylene bags and incubated in the laboratory between 25 - 28<sup>0</sup>C for three days. Fungal mycelium that developed from the tissue sections was transferred onto potato-dextrose agar (PDA) plates. Pure isolates were kept on PDA slants and stored in a refrigerator until needed.

Morphological characteristics were viewed with a compound microscope with distilled water and lactophenol as mountants. Conclusive identification of isolates was made based on growth rate, colour of cultures, morphology of mycelia, conidia characteristics and sporulating structures (Thom and Raper, 1945; Ekundayo and Haskins, 1969; Booth, 1971; Barnett and Hunter, 1972; Ramirez, 1982; Samson and van Reenen-Hoekstra, 1988).

Medium-sized sound cormels of Amankanipa, Amankanifitaa and Amankani Serwa varieties free from wounds were used for testing the pathogenicity of isolates. The method employed was similar to that described previously for inoculating cocoyam (Maduewesi and Onyike, 1980) and yam (Cornelius, 1998). Cormels were thoroughly washed in running tap water for ten minutes, surface sterilised in 5% sodium hypochlorite solution (commercial bleach) and air-dried for four minutes. Before inoculating, the point of inoculation was wiped with 95% ethanol.

A sterile 5 mm diameter cork borer was used to make wells on the cormels to a depth of about 8 mm. Mycelial plugs from the periphery of actively-growing four-day old cultures of the fungi to be tested were removed and placed into the wells. The openings of the wells were again wiped with 95% ethanol and the wells occluded with tissue plugs before sealing with melted paraffin wax (Fig. 1). Discs of sterile PDA were used as control. Each isolate was used to inoculate five cormels of each variety.

The inoculated cocoyams were kept in an incubating chamber in the laboratory for 10 days. The temperature during the period ranged between 26 and 30<sup>0</sup>C with a relative humidity (R. H.) range of 50 to 80%. At the end of the storage period, cormels were cut transversely through the points of inoculation and rot symptoms recorded and compared with symptoms observed previously in diseased cormels. Re-isolation and identification of micro-organisms from inoculated cocoyam cormels were also done. An isolate was confirmed pathogenic if the re-isolated organism had similar culture and morphological characteristics as the previously isolated organism.

### **3.3. Effect of duration of cormel storage on weight loss, sprouting and incidence and origin of rots in Amankanipa, Amankanifitaa and Amankani Serwa**

Cocoyam cormels of the Amankanipa, Amankanifitaa and Amankani Serwa varieties were obtained from a farmer's field at Awaham near Asamankese in the Eastern Region and transported within five hours to the Crop Science Department,



**Figure 1.** Inoculated cocoyam cormels to determine pathogenicity of isolates.

Note: Inoculated points sealed with paraffin wax.

University of Ghana, Legon. The experiment was conducted between December, 1997 and April, 1998. Sound, unbruised cormels were sorted out and used for the experiment. Twenty cormels of each variety constituted a treatment (four replications per treatment).

Cormels were serially labelled, weighed and put into polysacks measuring 40 cm x 30 cm. They were tied and stored on shelves in a wooden barn at the Sinna's garden, Crop Science Department. Treatments were arranged in a randomised complete block design (RCBD), each shelf constituting a block (Fig. 2).

The barn has a wooden roof and the sides covered with wire mesh and measured 3.8 m x 2.0 m x 2.2 m. The temperature in the barn ranged from 26 - 34<sup>0</sup>C and a R.H. of between 35 - 85% recorded with a thermohydrograph. Cormels were examined weekly for weight loss, sprouting and incidence of rots over a period of 16 weeks. Estimates of weight loss and sprouting were based on number of cormels remaining (survivors) after rotten ones had been progressively removed. Percent weight loss computations were made by comparing the mean weights of the number of cormels remaining at the end of a week (survivors) to the mean weight of the same cormels taken at the start of the experiment. A cormel was judged as sprouted just when sprouts begin to emerge from opened buds. Rotten cormels were identified by inspection for shrivelling and/or softness to touch. Exudation of fluid from the point of rot also confirmed soft rot. Each rotten cormel was carefully examined to ascertain and establish the origin of rots including the 'natural' wounds.



**Figure 2.** Cocoyam cormels of the Amankanipa, Amankanifitaa and Amankani Serwa varieties enclosed in sacks and arranged on shelves of wooden barn for shelf life studies.

Note: A thermohydrograph used for recording temperature and relative humidity in the barn (arrowed).

Rotten cormels were taken to the laboratory and used for isolation of micro-organisms associated with rots as described in section 3.2. Analysis of variance (ANOVA) and mean separation by Least Significance Difference (LSD) test were performed on the angular-transformed data.

### **3.4. Effectiveness of thiabendazole and lime in controlling rots in cocoyam cormels**

#### **3.4.1. Laboratory test**

This test was designed to assess the effects of thiabendazole and lime on the mycelial growth of isolates *in vitro*. It was also to help determine the appropriate concentrations of test chemicals to apply on cocoyam for the control experiment.

PDA was prepared as described and amended with thiabendazole at 0, 250, 500 and 1000 ppm and lime at 0, 50, 100 and 200 g/litre respectively. Because of the high viscosity and concentration (45%) of thiabendazole used, it was first diluted to a lower concentration with sterile distilled water. Aliquots were then added to the PDA to obtain the desired concentration. The pH of the lime was determined with a pH meter. The media were then dispensed into petri dishes. Mycelia from freshly-cultured fungal isolates namely *Aspergillus flavus*, *Botryodiplodia theobromae*, *Fusarium oxysporum*, *Fusarium solani*, *Penicillium citrinum*, and *Rhizopus stolonifer* were separately plated on these media with each isolate replicated three times.

Plates were incubated in the laboratory at 25 - 28<sup>0</sup>C and a R. H. of 53 - 75% and arranged in a completely randomised design (CRD). Growth inhibition was

assessed based on mean colony diameter measured in two directions at right angles. Percent degree of inhibition of mycelial growth was computed by the relation  $100(C - T)/C$ , where C and T are the diameters of the untreated (control) and the treated colonies, respectively.

#### 3.4.2. Effect of test chemicals on cocoyam cormels in storage

Freshly-harvested cocoyams of the Amankanipa variety were procured from a farmer's field at Awaham. These were transported within five hours to the laboratory at the Crop Science Department, University of Ghana. Unbruised cormels were randomly separated into three equal portions corresponding to three treatments; thiabendazole at 500 ppm, lime at 200 g/litre and a control, reflecting the appropriate concentration obtained from the *in vitro* study.

Since earlier experiments had shown that in 92.2% of this variety of cocoyam infection originates at the point of detachment from the mother corm (proximal end) where a 'natural' wound is created during harvesting, chemical treatment targeted at this point was deemed important.

To ensure uniform wounds, a thin slice of tissue was cut from the proximal end. These points were immersed in the respective preparations for 30 seconds each. The control treatment consisted of sliced off but untreated cormels. Treatments were left to air-dry for 24 hours and were put into polysacks measuring 72 cm x 43 cm and stored on shelves in the wooden barn in the Sinna's garden at the Crop Science Department (Fig. 3). Each treatment consisted of 50 cormels and was replicated four times. Treatments were arranged in a randomised complete



**Figure 3.** Amankanipa variety of cocoyam treated with 0.05% thiabendazole and 200 g/litre lime enclosed in sacks and randomly arranged on shelves of wooden barn.

Note: The thermohydrograph used for recording temperature and relative humidity in the barn.

block design (RCBD). The temperature range during the period was 24 - 31°C with a r. h. range of 53 - 84%.

Cormels were sampled fortnightly for 10 weeks (May - July, 1998). Ten cormels were randomly selected on each sampling day and sectioned longitudinally through the proximal end. They were then examined carefully so that the origin of rots could be ascertained and the extent of rotting measured by tracing the outline on a graph sheet and counting the number of squares. Analysis of variance (ANOVA) and mean separation by LSD test were done on data collected.

## CHAPTER FOUR

### RESULTS

#### 4.1. Survey Results

##### 4.1.1. Popular Ghanaian cocoyam varieties, their characteristics and consumer preferences

In a market situation and considering cormel skin colour as well as the colour of the lateral and terminal buds, two varieties i.e. the pink and white varieties were identified. At the farm level, however, and considering the colour of petiole margins, the reddish-purple and green varieties were obvious. Combining the colour of the cormel skin and that of petiole margins, three distinct varieties could be described. These are the Amankanipa, Amankanifitaa and Amankani Serwa varieties (Fig. 4). The pink variety, however, is more popular than the white varieties. The characteristics of these varieties are;

'Amankanipa': This variety is a large plant with dark-green leaves and reddish-purple petioles margins. The base of the leaves at the soil level is pink. Inner colour of cormels, terminal as well as lateral buds are pinkish (Fig. 4). After cooking, the pink cormel flesh colour turns mauve.



**Figure 4.** Varieties of cocoyam popularly grown and consumed in Ghana.

a) Amankanipa b) Amankanifitaa and c) Amankani Serwa

- i. The reddish-purple petiole margins of the Amankanipa and Amankanifitaa varieties.
- ii. The white cormels of the Amankanifitaa and Amankani Serwa varieties
- iii. Amankanifitaa variety shares the features of both the Amankanipa and Amankani Serwa varieties. viz. the reddish-purple petiole colour of the Amankanipa variety and the white cormel colour of the Amankani Serwa variety.

Note: Three photographs were taken at three separate parts of the plant to give prominence to the features of interest.



'Amankanifitaa': The above-ground parts of this variety resemble Amankanipa with deep-green leaves and reddish purple petiole margins. Unlike the Amankanipa, however, the base of the leaves of this variety just above the soil level is pale-green (Fig. 4). Cormel flesh colour as well as the colour of terminal and lateral buds is white.

'Amankani Serwa': The base of this plant as well as the submerged portions resemble the Amankanifitaa variety. However, leaves and petiole margins are pale-green in colour (Fig. 4).

Retailers (100%) indicated that they prefer the pink variety to the white as that is the variety consumers prefer. Whereas 65% of consumers prefer the pink variety, 10% prefer the white and 25% have no preference for either variety. Most retailers (97.6%) attributed this to the ability of the pink variety to impart an attractive mauve colour to 'fufu' ( a popular Ghanaian dish). On the contrary, 60% of consumers prefer the pink variety because of its desirable taste, 15% of them mentioned the colour it imparts to 'fufu' whilst 25% of them have no obvious reason.

#### 4.1.2. Sources of cocoyam to retailers and consumers and regions in Ghana where they are obtained

Table 2 shows the sources of cocoyam to retailers and consumers in Accra. All cocoyam retailers in Agbogbloshie and Kaneshie markets obtain their supplies through middlemen whilst 95.7% and 75.0% of retailers in Mallam Atta and

Madina markets respectively obtain them from that source. 12.5% and 4.3% of those in Madina and Mallam Atta markets respectively obtain their supplies directly from farm gate. Only 12.5% of retailers at Madina market buy from village markets. None of the retailers interviewed obtain cocoyam from their personal farms. Of the number of consumers interviewed, however, 82.5% obtain cocoyam from the urban markets while 17.5% obtain it from their personal farms.

The survey also indicates that cocoyam retailers in Accra obtain their supplies from five out of the 10 regions in Ghana (Table 2). These are Eastern (67.0%), Ashanti (14.7%), Brong Ahafo (13.5%), Central (3.6%) and Volta (1.2%) regions.

**Table 2.** Sources of cocoyam to retailers and consumers in Accra.

Source of supply	Percent of respondents				
	Agbogbloshi market	Mallam Atta market	Madina market	Kaneshie market	Consumers
Personal farm	0.0	0.0	0.0	0.0	17.5
Farm gate	0.0	4.3	12.5	0.0	0.0
Village market	0.0	0.0	12.5	0.0	0.0
Middlemen	100.0	95.7	75.0	100.0	0.0
Urban market	0.0	0.0	0.0	0.0	82.5
Total	100.0	100.0	100.0	100.0	100.0

Regions in Ghana where retailers obtain cocoyam for sale in Accra is shown in Table 3. Major areas in the Eastern region where cocoyam is obtained include

Osino, Adawso, Koforidua, Asamankese, Begoro and Apedwa. Others are Bososo, Nkawkaw, Akim-Oda, Asesewa, Suhum, Anum Apapam, Potroase, Akyiansa, Ofoase and Bepong.

**Table 3.** Regions in Ghana where cocoyam is obtained for sale in Accra

Region	Percent of respondents			
	Agbogbloshie market	Mallam Atta market	Madina market	Kaneshie market
Eastern	83.2	41.6	87.5	61.7
Central	4.2	0.0	0.0	10.0
Brong Ahafo	0.0	29.2	0.0	21.7
Ashanti	8.4	29.2	12.5	6.6
Volta	4.2	0.0	0.0	0.0

Areas in the Ashanti region include Tapa, Agogo and Obogu. In the Brong Ahafo region, the major areas include Techiman, Sunyani and Goaso. In the Central region, the towns include Odoben and Brakwa while Kadjebi is the only town mentioned for Volta region. All these towns happen to fall in the tropical rainforest belt where cocoa is extensively grown.

The quantity of cocoyam purchased per week varies from retailer to retailer and from market to market in Accra (Table 4). Generally, retailers in Agbogbloshie market buy more cocoyam per week compared to those of the other markets. This is as a result of the size of the market as well as its proximity to the business centre of Accra. About sixty-six percent of retailers in Agbogbloshie market purchase between five to ten sacks\* of cocoyam per week. This compares

with 41.7% at Mallam Atta market who purchase the same quantity per week (A sack measures 90 cm x 54 cm and could contain about 500 average-sized cocoyam cormels). Exactly half the number of retailers at Madina market

**Table 4.** Weekly supplies of cocoyam from middlemen in four markets in Accra

Quantity/week	Weight+ (tonnes)	Percent of respondents			
		Agbobbloshie market	Mallam Atta market	Madina market	Kaneshie market
1 - 2 sacks*	0.15 – 0.30	0.0	25.0	25.0	30.0
3 - 4 sacks	0.45 – 0.60	16.7	33.3	50.0	40.0
5 – 10 sacks	0.75 – 1.50	66.6	41.7	12.5	30.0
Over 10 sacks	> 1.50	16.7	0.0	12.5	0.0
Total		100.0	100.0	100.0	100.0

\*A sack measures 90 cm x 54 cm and could contain about 500 average-sized cocoyam cormels  
+Calculation is based on a mean cormel weight of 300 g.

buy three to four sacks of cocoyam per week while 40.0% of retailers at Kaneshie buy the same quantity per week. The reasons advanced for this trend are just as variable. Some respondents (30.3%) attributed it to the low patronage by consumers as opposed to other staples like cassava, yam and plantain. Others (48.6%) mentioned problems associated with storage whilst 15.8% blame it on the limited supply compared to demand.

#### 4.1.3. Harvesting time, handling and transportation of cocoyam

Respondents in the four cocoyam markets gave a wide range of period over which cocoyam is harvested and made available to consumers. Some respondents mentioned the periods from November - January as the time when harvesting is at its peak. Others (3.6%) put this period between February and March, 40.1% gave April to May while 9.8% mentioned June and beyond.

Prior to transportation, cocoyam is mainly stored in polysacks (90.5%) even though it is sometimes stored in baskets (7.1%) or spread on the floor (2.4%). In this condition, cocoyam is kept for a maximum of two days (63.8%) before being transported to marketing centres. The major means of transport is by road (96.4%) and by rail (3.6%). Transportation is done in sacks (100%) and is accomplished either within a day (52.4%) or in two days (47.6%).

#### 4.1.4. Cocoyam storage by retailers in four markets and consumers in Accra

Cocoyam is predominantly stored on the market (90.5%) even though some respondents (9.5%) store them in their homes and carry them in bits to the markets. Whether in the market or at home, cocoyam is stored in two ways. Most retailers (90.5%) store them in sacks while a few store them in big baskets covered with jute sacks. Consumers, on the other hand, have a wide variety of ways by which they store the cocoyam. These include the use of polythene and jute sacks (23.5%), in pits (38.3%), on bare floor (17.6%), on platforms (5.9%) or peeled and stored in deep freezers (11.8%).

The duration of cocoyam storage by retailers and consumers in Accra hardly extends beyond four weeks (Table 5). Most retailers in three markets store their

cocoyam for less than one week. These are Agboglobshie market (91.7%), Madina market (37.5) and Kaneshie market (60.0%). It became evident that most retailers dispose of their stocks before the end of the first week. This is to forestall excessive losses as a result of unreliable storage conditions. A few consumers are, however, able to store cocoyam for over four weeks apparently due to the small quantities they handle.

**Table 5.** Duration of cocoyam storage by retailers and consumers in Accra

Duration of storage	Percent of respondents				
	Agboglobshie market	Mallam Atta market	Madina market	Kaneshie market	Consumers
Less than one week	91.7	8.3	37.5	60.0	29.4
One week	8.3	58.4	37.5	30.0	35.3
Two weeks	0.0	25.0	12.5	10.0	17.6
Four weeks	0.0	8.3	12.5	0.0	11.8
Over four weeks	0.0	0.0	0.0	0.0	5.9
Total	100.0	100.0	100.0	100.0	100.0

#### 4.1.5. Cocoyam storage problems encountered by retailers and consumers in Accra

Problems associated with cocoyam storage constitute one of the key issues that came up during the survey. This is a major contributory factor to the low demand of the product per head at any particular time. Problems encountered during storage include rotting (85.7%), sprouting (92.9%) and dehydration (92.9%). Rots of stored cocoyam originated either from the proximal ends (point

of detachment from mother corm), lateral sides or from the distal ends of cormels (Fig. 5). In the absence of injuries to the lateral or distal ends, however, most rots were found to originate from the proximal ends of cormels. It was also learnt that the susceptibility of the pink and white cocoyam varieties to these storage problems varies.

Table 6 shows percent cormel rot encountered by retailers and consumers in Accra. It is evident from Table 6 that only a few respondents encounter cormel rot of over 10 percent. This is because the extent of rot is compensated for by the low demand-supply relationship which enables stocks to be disposed of within a week. On the question of varietal susceptibility to rot, sprouting and dehydration, most respondents were not quite certain since storage at their level takes such a short time.

**Table 6.** Percent cormel rot encountered by cocoyam retailers and consumers in Accra

Weekly cormel rot (%)	Percent of respondents				
	Agbogbloshie market	Mallam Atta market	Madina market	Kaneshie market	Consumers
0 – 5	100.0	40.0	87.5	83.3	89.5
6 – 10	0.0	50.0	12.5	0.0	10.5
10 – 20	0.0	10.0	0.0	16.7	0.0
Total	100.0	100.0	100.0	100.0	100.0



**Figure 5.** Longitudinal section of cocoyam cormels showing origin of natural rots induced by rot-causing fungi at different parts of cormels.

Left: Lateral side

Middle: Both proximal and mostly distal

Right: Proximal end

However, while 11.1% of respondents notice that the pink variety rots earlier than the white variety 16.7% think otherwise, whereas 69.4% of them think both rot to the same extent. With regard to sprouting, 22.5% of respondents mentioned that it occurs more in the pink variety whilst 77.5% rank both equally. Most respondents see both varieties as having the same rate and degree of dehydration. Other storage problems include damage caused by mice (76.5%), termites (23.5%), red ants (5.9%) and cockroaches (11.8%).

#### 4.1.6. Preservation of fresh cocoyam

Some consumers preserve the quality of cocoyam cormels by burying them in the ground (5.0%) or by peeling them and keeping them in deep freezers (7.5%). A few retailers also sprinkle water on the cocoyam while in their sacks apparently to check excessive dehydration during storage. However, practically no measures are taken by respondents to control rots in cocoyam cormels.

## 4.2. **Isolation and identification of rot-causing micro-organisms in cocoyams and proof of pathogenicity**

### 4.2.1. Description of isolates obtained from partially rotten cocoyam cormels

Isolations made from partially rotten cocoyam cormels sampled from two locations, that is, i) the four markets in Accra and ii) the storage barn yielded six fungal species responsible for rots in cocoyam. These were: *Aspergillus flavus* Link; *Botryodiplodia theobromae* Pat. *Fusarium oxysporum* Schlecht; *Fusarium solani* (Mart.) Sacc.; *Penicillium citrinum* Thom; *Rhizopus stolonifer* (Ehrenb)

Lind. Identification of isolates were based on the following culture and morphological characteristics:

#### *Aspergillus flavus*

Culture on PDA was made up of a dense felt of yellowish-green colour attaining a diameter of 5.0 - 6.5 cm in 7 days. Mycelial growth was usually in concentric rings (Fig. 6). Conidial heads radiated, later splitting into several loose columns, yellowish-green becoming dark-yellow-green. Conidiophores hyaline, vesicle globose with phialides borne directly on them, conidia globose to sub-globose (Fig. 7) and measured 3.6  $\mu\text{m}$ .

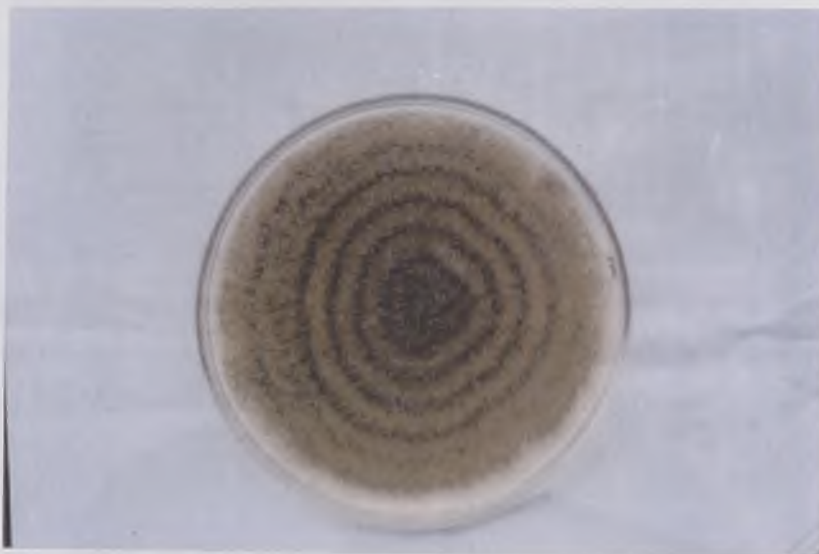


#### *Botryodiplodia theobromae*

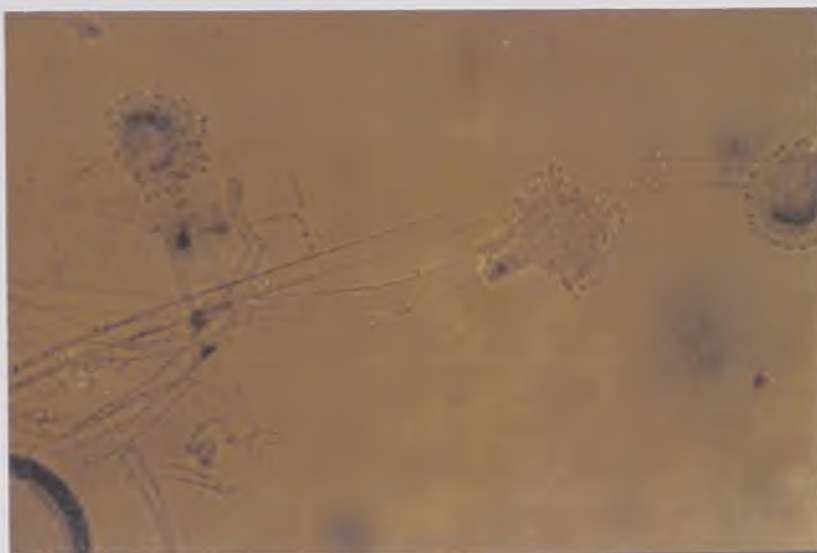
Culture on PDA filled a 9.0 cm diameter plate in 48 hours. It consisted of a fluffy aerial mycelium, grey initially but turned black after 5 days (Fig. 8). Cultures on PDA and cornmeal agar (CMA) kept about 45 cm below a two feet fluorescent light in an incubating chamber produced pycnidia from stromata (Fig 9) in which ellipsoidal conidia (pycnidiospores) were produced. Spores were hyaline and aseptate when immature but matured into 2-celled dark-brown spores (Fig. 10).

#### *Fusarium oxysporum*

Colonies on PDA attained a diameter of 5.5 cm in 7 days. Aerial mycelium was sparse and became light-orange with a light-purple tinge later developing at



**Figure 6.** Ten-day old culture of *Aspergillus flavus* on potato-dextrose agar plate (x 0.6). Note: the concentric rings within mycelium with yellowish-green spore masses.



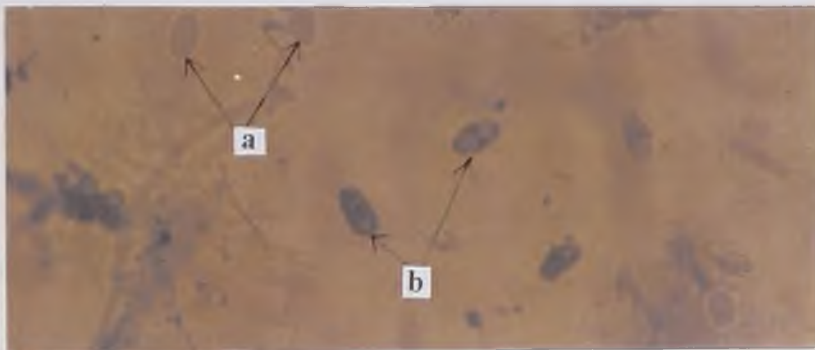
**Figure 7.** Conidial head and conidia of *Aspergillus flavus* (x 800). Note: the globose vesicle and conidia.



**Figure 8.** Young and old cultures of *Botryodiplodia theobromae* on potato-dextrose agar plates (x 0.5). Note: Three-day old culture with greyish aerial mycelium (left) and ten-day old culture with dark-coloured mycelium (right).



**Figure 9.** Pycnidia production by *Botryodiplodia theobromae* on potato-dextrose agar (left) and cornmeal agar (right) plates kept under fluorescent light for fourteen days (x 0.4)



**Figure 10.** Conidia of *Botryodiplodia theobromae* produced in pycnidia of a seventeen-day old culture (x 800).

- a) One-celled immature conidia
- b) Two-celled dark-brown mature conidia.

the older parts of the culture (Fig. 11). Micro-conidia were elliptical and borne on lateral, simple phialides. Macro-conidia elongated and pointed at both ends and borne on phialides on short much-branched conidiophores (Fig. 12). Chlamydo spores hyaline, rough-walled, terminal or intercalary.

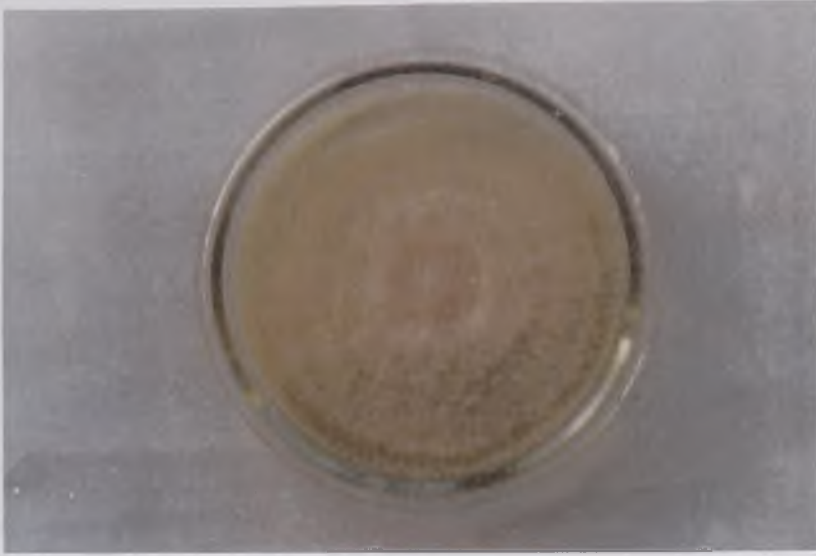
#### *Fusarium solani*

Colonies on PDA attained a diameter of 5.5 - 7.0 cm in 7 days. Aerial mycelium was dense, sometimes leathery, greyish-white to cream (Fig. 13). Micro-conidia abundant, ovoid or oblong, 0 - 1 septate formed from elongated conidiophores. Macro-conidia formed from short multi-branched conidiophores which may form sporodochia, 3 - 5 septate, fusiform, cylindrical often moderately curved (Fig. 14). Chlamydo spores hyaline, smooth or rough-walled, globose to ovoid.

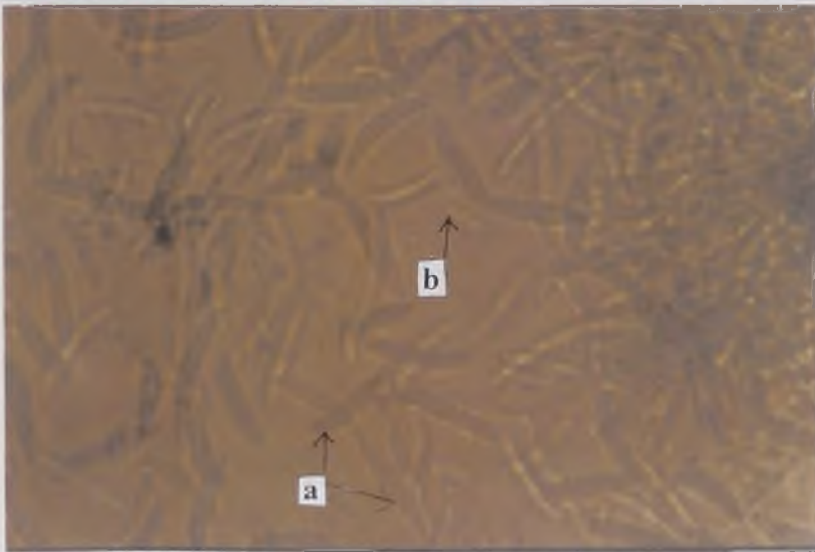
#### *Penicillium citrinum*

Colonies on PDA growing restrictedly, attaining a diameter of 3.0 - 4.0 cm in 7 days. They consist of a dense felt of conidiophores sometimes appearing leathery and blue-green in colour. Reverse culture normally yellow to orange (Fig. 15). Conidiophores biverticillate and smooth-walled. Metulae terminate in a whorl of 6 - 10 phialides. Phialides flask-shaped, conidia produced in columns, globose to sub-globose, smooth-walled or finely rough and hyaline in colour (Fig. 16).





**Figure 11.** Ten-day old culture of *Fusarium oxysporum* on potato-dextrose agar plate (x 0.5)

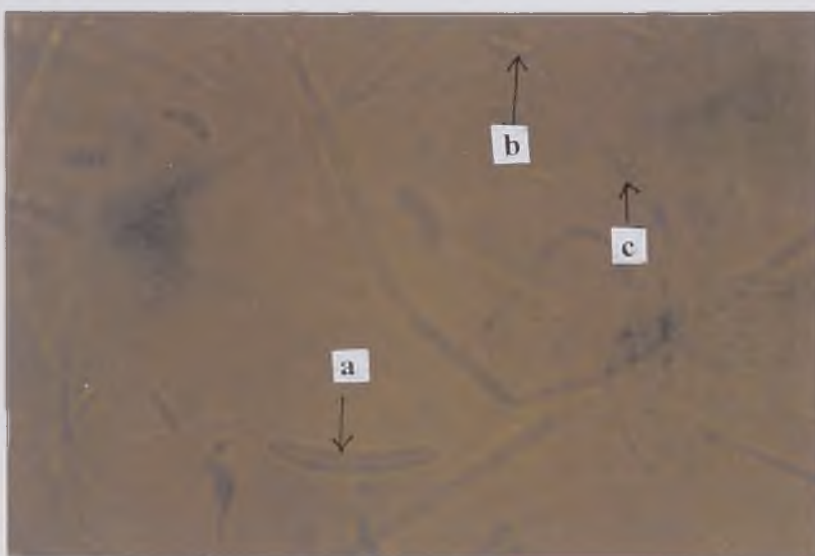


**Figure 12.** Conidia of *Fusarium oxysporum*. (x 1600)

a) Macro-conidia b) Micro-conidium

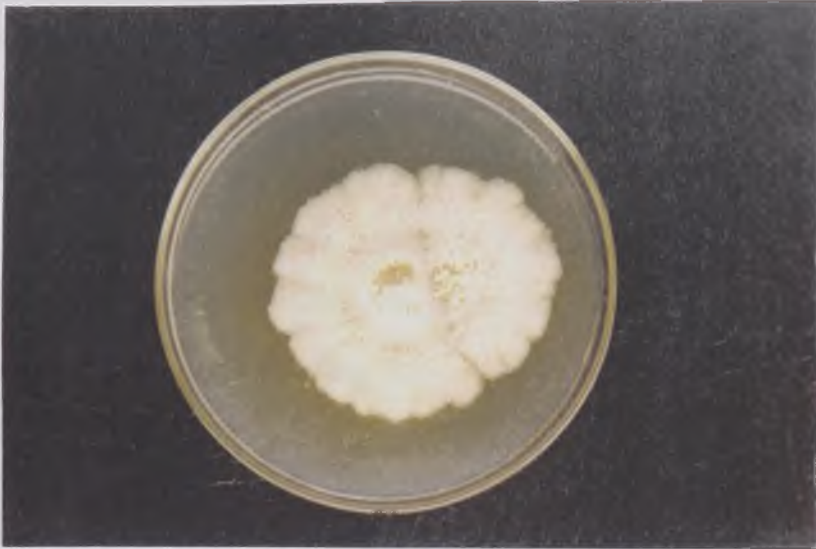


**Figure 13.** Seven-day old culture of *Fusarium solani* on potato-dextrose agar plate (x 0.6)



**Figure 14.** Conidia of *Fusarium solani* (x 800).

a) Macro-conidium b) Micro-conidium c) Elongated conidiophore.



**Figure 15.** Ten-day old culture of *Penicillium citrinum* on potato-dextrose agar plate (x 0.6).



**Figure 16.** Structure of *Penicillium citrinum* under light microscope (stained) (x 800).

Note: Metulae with flask-shaped phialides

*Rhizopus stolonifer*

Culture filled a 90.0 mm diameter plate in 2 days. The fluffy mycelium was whitish becoming greyish-brown with time (Fig. 17). Smooth-walled and aseptate sporangiophores were in groups arising from stolons opposite the branched rhizoids. Sporangia measured about 150  $\mu\text{m}$  in diameter, globose and brownish at maturity with globose columella (Fig. 18).

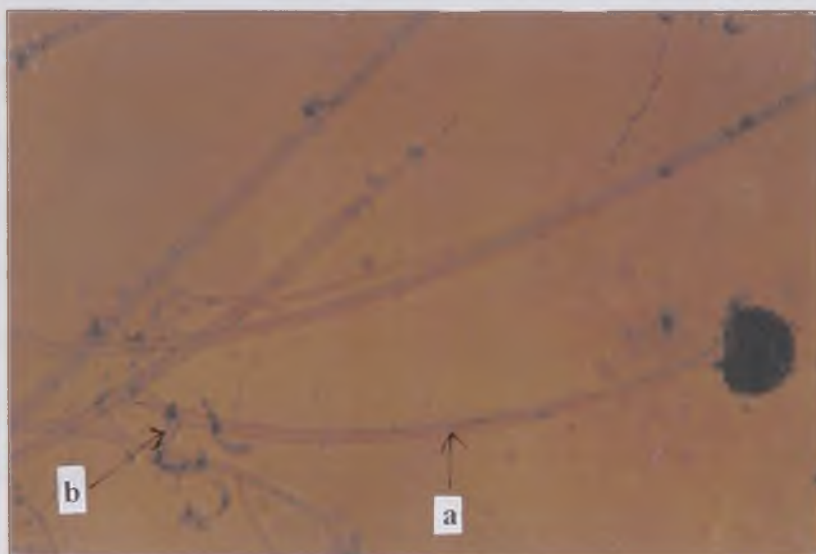
#### 4.2.2. Frequency of occurrence of micro-organisms in partially-rotten cocoyam cormels

Table 7 shows the frequency of occurrence of micro-organisms responsible for rots in cocoyam cormels. With the market samples, all six fungal isolates were encountered. *Fusarium solani* and *Botryodiplodia theobromae* constituted the most frequently occurring organisms (30% each). These were followed by *Penicillium citrinum* (16.7%) and *Fusarium oxysporum* (13.3%). *Rhizopus stolonifer* had a frequency of 6.7% with the least encountered organism being *Aspergillus flavus* (3.3%).

In the case of samples obtained from the storage barn, *Fusarium solani* was the most frequently occurring organism (51.4%) followed by *Fusarium oxysporum* (37.0%). *Botryodiplodia theobromae* was next with a frequency of 6.6% followed by *Rhizopus stolonifer* and *Aspergillus flavus* (2.0% each) with the least encountered being *Penicillium citrinum* (1.0%). Generally, the two *Fusarium* species (*F. oxysporum* and *F. solani*) altogether constituted 77.2% of the total isolations made.



**Figure 17.** Five-day old culture of *Rhizopus stolonifer* on potato-dextrose agar plate (x 0.6)



**Figure 18.** Structure of *Rhizopus stolonifer* under light microscope (x 800).

- a) sporangiophore arising from a point on a stolon
- b) rhizoids opposite the sporangiophore

**Table 7.** Frequency of occurrence of micro-organisms in partially rotten cocoyam cormels obtained from some markets in Accra and storage barn.

Isolate	Frequency (%)		
	Markets	Storage barn	Mean
<i>Aspergillus flavus</i>	3.3	2.0	2.4
<i>Botryodiplodia theobromae</i>	30.0	6.6	12.2
<i>Fusarium oxysporum</i>	13.3	37.0	31.7
<i>Fusarium solani</i>	30.0	51.4	45.5
<i>Penicillium citrinum</i>	6.7	1.0	4.9
<i>Rhizopus stolonifer</i>	6.7	2.0	3.3

Figure 19 shows the result of pathogenicity test of isolates. The test revealed that even though isolations were made from randomly selected cocoyam samples, pure cultures of all the six fungal isolates were pathogenic to healthy cocoyam cormels of the three varieties (Amankanipa, Amankanifitaa and Amankani Serwa) after eleven days of incubation. The test also showed that virulence varied amongst test pathogens. *Botryodiplodia theobromae*, *Fusarium oxysporum* and *F. solani* were more virulent compared to *Aspergillus flavus*, *Penicillium citrinum* and *Rhizopus stolonifer*.



**Figure 19.** Transverse section of Amankanipa, Amankanifitaa and Amankani Serwa varieties of cocoyam showing rots induced in inoculated tissues by test fungi eleven days after incubation. Note: Arrangement of isolates:

- o) Control
- a) *Fusarium solani*
- b) *Fusarium oxysporum*
- c) *Rhizopus stolonifer*
- d) *Aspergillus flavus*
- e) *Penicillium citrinum*
- f) *Botryodiplodia theobromae*

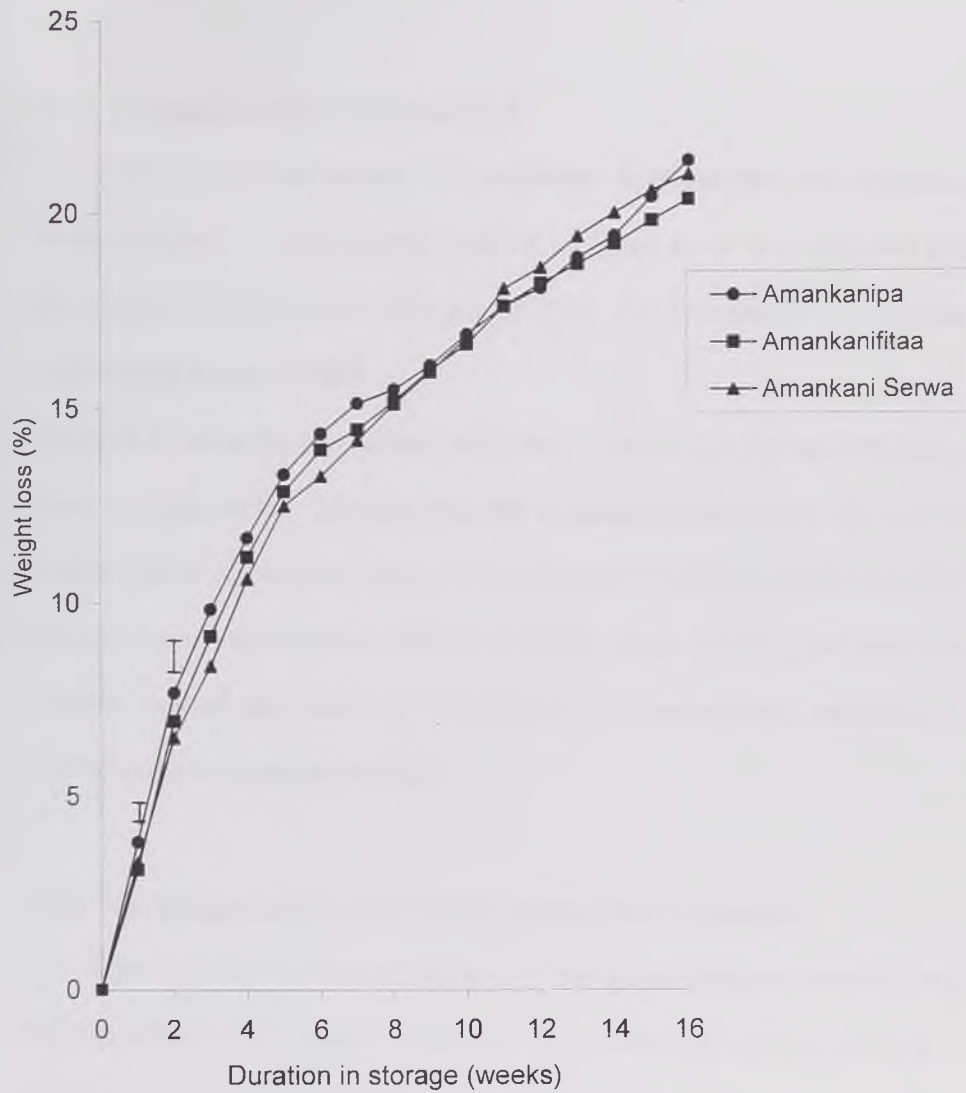
Furthermore, the test revealed that the type of tissue discoloration varies among both varieties and pathogens. The two *Fusarium* species produced a brownish-black discoloration in both the Amankanipa and Amankanifitaa varieties whereas in the Amankani Serwa variety, a brownish discoloration was produced. However, *Aspergillus flavus*, *Penicillium citrinum* and *Rhizopus stolonifer* all produced grey to brownish-grey discoloration in all three varieties.

#### **4.3. Effect of duration of cormel storage on weight loss, sprouting as well as incidence and origin of rots in Amankanipa, Amankanifitaa and Amankani Serwa**

##### **4.3.1. Weight loss in three cocoyam varieties**

Figure 20 shows the percent cormel weight loss of the three varieties during a sixteen-week storage period. All varieties showed steady increases in cormel weight loss during the study period. However, cormels of Amankanipa recorded a consistently higher cormel weight loss during the first 10 weeks of storage recording 16.83% at the 10th week compared to both Amankanifitaa (16.59%) and Amankani Serwa (16.74%) varieties even though this was significant ( $P=0.05$ ) only in the first two weeks.

Thereafter, weight loss in Amankani Serwa cormels displaced those of Amankanipa and Amankanifitaa up to the 15th week of storage after which Amankanipa cormels recorded the highest weight loss reaching a peak of 21.27% at the 16th week compared to 20.28% and 20.91% for Amankanifitaa and



**Figure 20.** Percent cormel weight loss in Amankanipa, Amakanifitaa and Amankani Serwa varieties during storage  
(Note: Vertical bars represent L.S.D. at P=0.05)

Amankani Serwa respectively even though there were no significant differences among them.

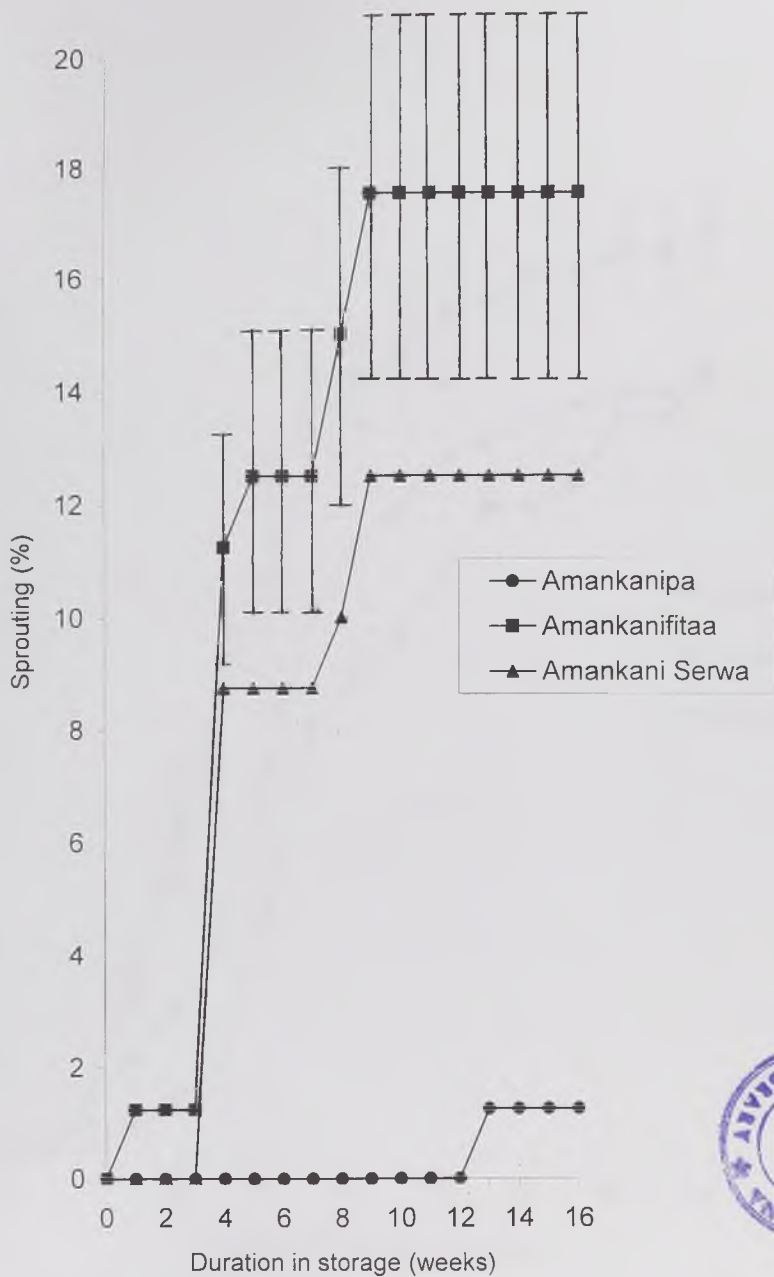
#### 4.3.2. Sprouting in three cocoyam varieties

Results of cormel sprouts in Amankanipa, Amankanifitaa and Amankani Serwa varieties of cocoyam are presented in figure 21. It was observed that sprouting in all three varieties was generally low. This is particularly so with the Amankanipa variety in which the onset of sprouting was delayed until after 13 weeks after storage. Sprouting, however, began in the Amankanifitaa and Amankani Serwa cormels in the first and fifth weeks respectively. These two varieties also recorded significantly higher ( $P=0.05$ ) cormel sprouts than in the Amankanipa variety. Sprouting in these two varieties reached their peaks of 17.5% and 12.5%, respectively, compared to 1.25% for the Amankanipa cormels.

#### 4.3.3. Incidence and origin of cormel rots in three cocoyam varieties

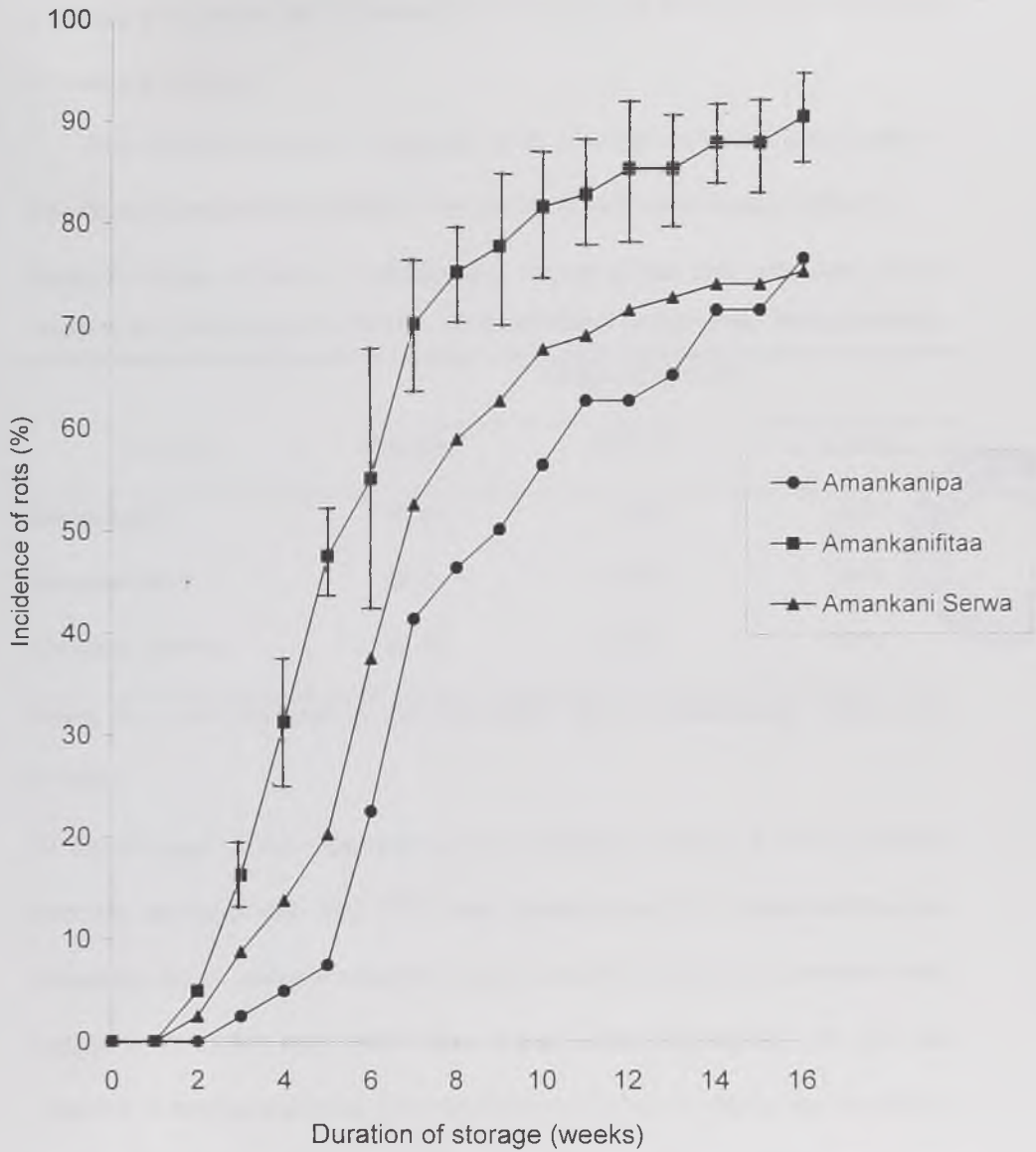
Figure 22 shows the percent incidence of rots in Amankanipa, Amankanifitaa and Amankani Serwa cormels. Generally, the Amankanipa variety recorded a significantly lower ( $P=0.05$ ) incidence of cormel rot during the study period. On the contrary, cormels of the Amankanifitaa showed a consistently higher incidence of rot compared to both the Amankanipa and Amankani Serwa varieties.

Incidence of rots started in both the Amankanifitaa and Amankani Serwa varieties from the second week with incidence of 5.0% and 2.5% respectively.



**Figure 21.** Percent cormel sprouts in Amankanipa, Amankanifitaa and Amankani Serwa varieties during storage

(Note: Vertical bars represent L.S.D. at P=0.05)



**Figure 22.** Incidence of cormel rots in Amankanipa, Amankanifitaa and Amankani Serwa varieties during storage  
(Note: Vertical bars represent L.S.D. at P=0.05)

These rose sharply to 70% and 52.5% respectively by the 7th week. In the Amankanipa variety, however, rots started in the third week at 2.5% and rose gradually to 41.3% by the 7th week but did not exceed 50% incidence until after 10 weeks in storage.

Rots of stored cormels originated either from the proximal ends (point of detachment from mother corm), or from the lateral sides of cormels (Table 8).

**Table 8.** Origin of rots in Amankanipa, Amankanifitaa and Amankani Serwa varieties as a percentage of total rots observed after a sixteen-week storage period.

Variety	Origin of rots (%)		
	Proximal	Lateral	Distal
Amankanipa	92.2a	7.8b	0.0c
Amankanifitaa	86.2a	13.8b	0.0c
Amankani Serwa	85.1a	14.9b	0.0c

Means in a row followed by the same letter are not significantly different at  $P=0.05$ .

Of the 62 cases of rots observed in the Amankanipa variety, 92.2% originated from the proximal ends and 7.8% from lateral sides. The Amankanifitaa and Amankani Serwa cormels recorded 86.2% and 85.1% from the proximal ends compared to 13.8% and 14.9% from lateral sides respectively. No rot was observed as having originated from the distal end of any of the rotten cormels. In all varieties, rots which originated from the proximal ends of cormels were significantly higher than those from the lateral sides which were also significantly higher than those from the distal ends at  $P=0.05$ .

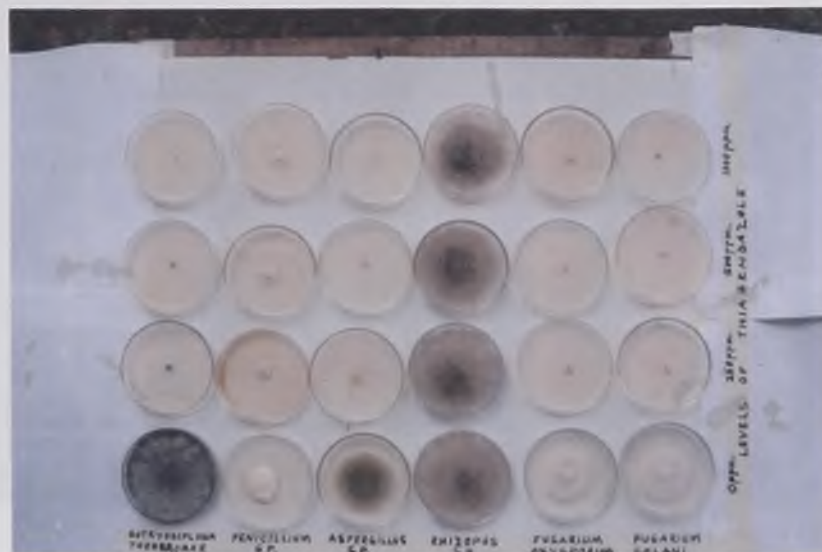
#### 4. Effectiveness of thiabendazole and lime in controlling rots in cocoyam cormels

##### 4.5.1. Laboratory studies on the effect of test chemicals on the growth of isolates

Figures 23 and 24 show the effect of three levels each of thiabendazole and lime on inhibition of diametric growth (mm) of isolates in culture incubated at room temperature and relative humidity values of 25 - 28<sup>o</sup>C and 53 - 75% respectively for seven days. Measurement of growth diameters is also presented in Table 9.

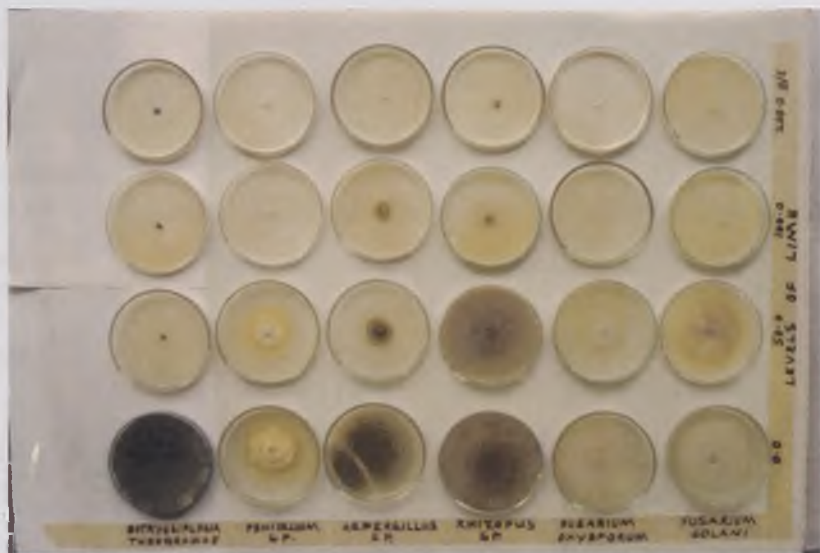
All thiabendazole levels were effective in completely inhibiting the growth of four out of the six isolates (Fig. 23; Table 9). These were *Aspergillus flavus*, *Botryodiplodia theobromae*, *Fusarium oxysporum* and *F. solani*. None of the thiabendazole levels was effective on *Rhizopus stolonifer* even though on visual observation higher concentrations restricted the aerial fluffy growth typical of this fungus. The growth of *Penicillium citrinum* was restricted at all concentrations of thiabendazole with percent inhibition of 53.0%, 56.1% and 57.0% at 250, 500 and 1000 ppm respectively.

Analysis of variance revealed that for this treatment no significant differences existed among the various levels for *A. flavus*, *B. theobromae*, *F. oxysporum*, *F. solani*, and *P. citrinum*. Significant differences were, however, observed between the control and the various levels for these same organisms. In the case of *R. stolonifer* no significant differences were observed among the levels including the control.



**Figure 23.** Effect of three levels of thiabendazole on diametric growth of six fungal isolates seven days after incubation.

- Growth of *F. solani*, *F. oxysporum*, *A. flavus* and *B. theobromae* completely inhibited.
- R. stolonifer* largely unaffected by thiabendazole
- Growth of *P. citrinum* inhibited to various degrees at all three levels of thiabendazole.



**Figure 24.** Effect of three levels of lime on diametric growth of six fungal isolates seven days after incubation.

- Lime completely inhibited growth of *B. theobromae* at all three levels.
- Growth of *P. citrinum*, *R. stolonifer*, *F. solani* and *F. oxysporum* completely inhibited at 100 and 200 g/l levels but partially inhibited at the 50 g/l level.
- A. flavus* completely inhibited at the 200 g/l level but partially inhibited at both 50 and 100 g/l levels.

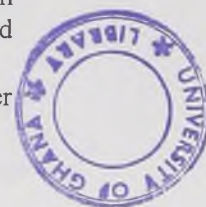
**Table 9.** Percent inhibition of diametric growth of fungal isolates on PDA amended with three levels each of thiabendazole and lime at seven days after incubation

Isolate	Percent inhibition							
	Thiabendazole (ppm)				Lime (g/litre)			
	0	250	500	1000	0	50	100	200
<i>Aspergillus flavus</i>	(66.3a) <sup>+</sup>	100* (0.0b)	100 (0.0b)	100 (0.0b)	(75.9a)	66.1 (25.7b)	86.6 (10.2c)	100 (0.0d)
<i>Botryodiplodia theobromae</i>	(90.0a)	100 (0.0b)	100 (0.0b)	100 (0.0b)	(90.0a)	100 (0.0b)	100 (0.0b)	100 (0.0b)
<i>Fusarium oxysporum</i>	(47.3a)	100 (0.0b)	100 (0.0b)	100 (0.0b)	(77.0a)	53.6 (35.7b)	100 (0.0c)	100 (0.0c)
<i>Fusarium solani</i>	(54.5a)	100 (0.0b)	100 (0.0b)	100 (0.0b)	(70.0a)	15.3 (25.7b)	100.0 (10.2c)	100 (0.0c)
<i>Penicillium citrinum</i>	(33.0a)	53.0 (15.5b)	56.1 (14.5b)	57.0 (14.2b)	(42.3a)	44.9 (23.3b)	100 (0.0c)	100 (0.0c)
<i>Rhizopus stolonifer</i>	(90.0a)	0.0 (90.0a)	0.0 (90.0a)	0.0 (90.0a)	(90.0a)	0.0 (90.0a)	77.0 (20.7b)	100.0 (0.0c)

\*Figures represent percent inhibitions derived from mean colony diameters of isolates cultured on amended PDA media replicated three times using the relation  $100(C - T/C)$  where C and T are the diameters of untreated (control) and treated colonies, respectively.

<sup>+</sup>Figures represent mean diameter of colonies (mm) cultured in 90.0mm diameter petri plates.

Means in a row (not column) under each treatment having the same letter are not significantly different at P= 0.05



The effect of lime on the growth of the isolates was even more variable. The highest concentration of 200 g/litre inhibited the diametric growth of all the isolates (Fig. 23; Table 9). At 100 g/litre, lime was effective on *B. theobromae*, *F. oxysporum*, *F. solani* and *P. citrinum*. However, only *B. theobromae* succumbed to lime at the 50.0 g/litre concentration. The remaining organisms had different growth rates at this concentration with *R. stolonifer* being unaffected.

Analysis of variance for the lime treatment indicated that for *F. oxysporum*, *F. solani* and *P. citrinum* with the exception of the 100 and 200 g/l levels which were not different, significant differences were observed between the 0 and 50 g/l levels which also recorded significant growth compared to the 100 and 200 g/l levels. In the case of *R. stolonifer* no significant differences were observed in the growth of cultures at the 0 and 50 g/l levels. There were, however, significant differences in the growth of this organism at the 100 and 200 g/l levels, which were also different from the 0 and 50 g/l levels. With *A. flavus*, significant differences were recorded at all treatment levels. In *B. theobromae*, however, no growth was observed at all levels with the exception of the control.

#### 4.5.2. Effect of thiabendazole and lime on rot size of cocoyam cormels in storage

Result on the effect of thiabendazole and lime on rot size of the Amankanipa variety of cocoyam is presented in figure 25. Treatments were targeted at the proximal ends of cormels since earlier experiments had revealed that this point constitute the dominant infection court for micro-organisms. The pH of the 20% lime was 12.40.

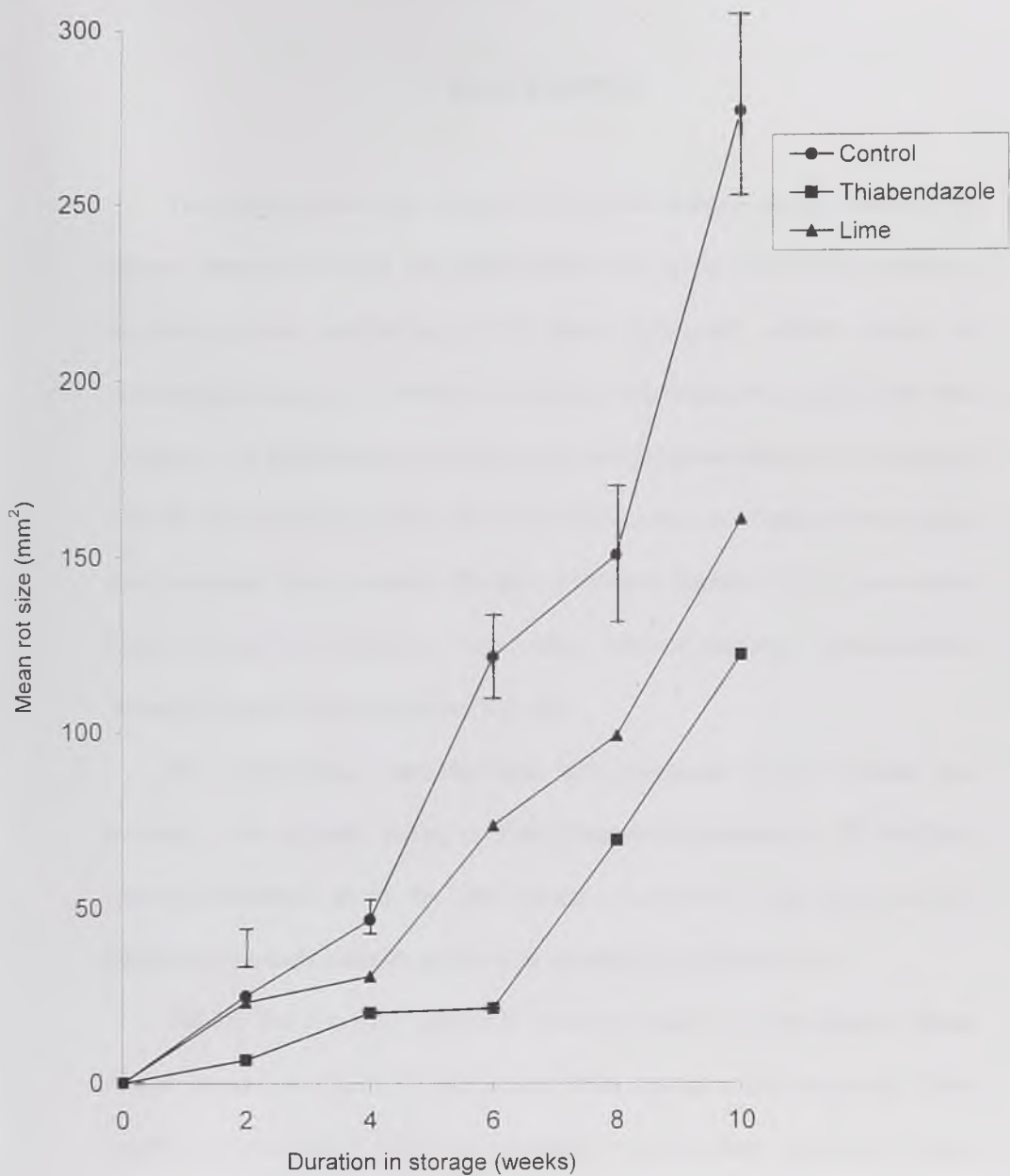
Rot size generally increased gradually during the first four weeks and then sharply thereafter. In the thiabendazole-treated cormels, rot size increased gradually from 6.7 mm<sup>2</sup> to 121.6 mm<sup>2</sup> after 10 weeks of storage. In the lime treatment rot size increased gradually during the first four weeks measuring 30.6 mm<sup>2</sup> and then sharply to 160.2 mm<sup>2</sup> at the tenth week.

Analysis of variance revealed significant differences in rot size between the thiabendazole and lime treatments for the second, fourth and sixth weeks respectively. Thereafter, no significant differences were observed between them.

Furthermore, with the exception of the second week during which no significant difference was observed between the control and lime treatments, significant differences were observed between the control, on one hand, and the thiabendazole and lime treatments, on the other.

Generally, the effectiveness of the two chemicals in controlling rots was evident. However, it was observed that thiabendazole was more effective in controlling rots in cocoyam than lime over the storage period.





**Figure 25.** Effect of thiabendazole and lime on rot size of the pink variety of cocoyam (Amankanipa) during storage  
(Note: Vertical bars represent L.S.D. at P=0.05)

## CHAPTER FIVE

### DISCUSSION

The survey revealed two varieties of cocoyam based on cormel flesh and skin colour. These are the pink and white varieties. At the farm level and considering the above-ground morphology of the plant (particularly petiole colour), the reddish-purple and green varieties are obvious. Combining these characters, three varieties – the Amankanipa, Amankanifitaa and Amankani Serwa were identified with the Amankanifitaa variety sharing the characteristics of both the Amankanipa and Amankani Serwa varieties. Wright (1930) and Karikari (1971) have earlier reported these in addition to three other varieties namely; Amankanifufuo, Amankani Antwibo and Amankani Kyirepe.

The Amankanipa, Amankanifitaa and Amankani Serwa varieties are, however, more popular owing to their commercial importance. Of the three varieties mentioned above, the pink variety is preferred to the white varieties apparently due to its superior taste and its suitability for making 'fufu'.

The fact that cocoyam supplies to Accra are mainly from the Eastern, Brong Ahafo, Ashanti, and parts of Central and Volta regions is not surprising. These regions lie in the tropical rainforest belt where cocoa is widely cultivated. Farmers in this zone cultivate cocoyam for two main reasons. It serves as ideal shade for the young cocoa seedlings (Karikari, 1971; Purseglove, 1972) and also provides food and income for farmers while the cocoa trees are still young. Eastern Region

contributes the bulk of Accra's cocoyam supplies because of its proximity to the capital city.

Retailers in Accra generally tend to buy a few sacks of cocoyam per week. This is not so much the result of low demand for the crop as losses incurred in storage if the crop is not sold. The low amounts of cocoyam purchased therefore are to ensure that stocks are disposed of within a week. Here lies the basis for the practice where the crop is left in the field and harvested as needed. Therefore, unlike yam which is harvested at its physiological maturity, harvesting of cocoyam is done over a longer period of time, from November in one year to June in the ensuing year i.e. within eight months. This practice could, however, be curtailed if lapses existing in the harvesting, handling and transportation of the crop are checked (with the view to reducing the degree of bruising to the cormels) and if storage conditions are improved upon.

Harvesting, packaging and transportation of cocoyam seem to create a number of wounds on the cormels, which serve as infection sites for pathogens. The process of loading and off-loading is done carelessly. Throwing and rolling of sacks full of cormels also produce multiple abrasions. These, together with the 'natural' wounds created at the point of detachment from mother corm, pre-dispose cormels to microbial infection.

The transportation of the produce in sacks packed in cargo trucks and covered with tarpaulin also creates high temperature and humidity conditions. Even though these conditions stimulate the development of a wound periderm



effective against microbial entry (Booth, 1974) they are also conducive for increased pathogenic activity (Booth, 1974).

Because of the limited space available to each retailer at the markets, cocoyam is kept together with other staples in a restricted area. These are usually left in the open leading to a build-up of heat in the afternoons and resulting in physiological and pathological damage to the cormels. Using perforated paper cartons for packaging and transportation under relatively low temperature conditions can check this. Since this has been found to increase the time taken to establish a rot as well as decrease the rate of spread (Tomkins, 1951). Ogundana (1976) reported an optimum temperature range of 26 - 30<sup>0</sup>C for rot of *X. sagittifolium* caused by *Fusarium solani* and *F. moniliforme*. Burton (1970) reported 22 - 29<sup>0</sup>C as optimal for cocoyam rot pathogens. These results indicate that rot caused by these fungal species could be minimised if cocoyams are stored at lower temperatures such as 10 - 15<sup>0</sup>C, that do not cause injury to the tissues (Onwueme, 1978).

Figures reported for cormel rots appear to be quite low (Table 6). These figures seem to have been compensated for by the relatively short post-harvest storage periods (mostly one week) as well as the ability of the crop to store in the field. The field storage of the crop is undoubtedly an expensive practice as it places undue restrictions on land availability. The solution to the problem of post-harvest losses therefore lies in the need to educate stakeholders such as farmers, middlemen and retailers on the production, distribution and sale of cocoyam and on factors contributing to excessive post-harvest losses and how these can be

minimised through intensive extension work. There is also the need for a systematic and in-depth research into identifying superior cocoyam varieties that could withstand rigorous post-harvest handling and facilitate prolonged shelf life.

Since the application of rot control measures is absent on the markets, attention should also be given to this area. Many chemical pesticides have been used in an attempt to control rots in root and tuber crops (Eckert and Kolbezen, 1964; Scott and Roberts, 1967; Thompson *et al.*, 1977). This has, however, not attracted the needed patronage particularly in the tropics apparently due to the possibility of toxic residues, the cost involved in pesticide use as well as their cumbersome application techniques. Studies aimed at identifying cheap but effective local materials for post-harvest treatment of cormels are, therefore, necessary.

The six fungal species that were frequently associated with storage rots of cocoyam were *Aspergillus flavus*, *Botryodiplodia theobromae*, *Fusarium oxysporum*, *Fusarium solani*, *Penicillium citrinum* and *Rhizopus stolonifer*. These findings partly agree with reports from various workers who isolated *Botryodiplodia theobromae*, *Fusarium oxysporum*, *Fusarium solani*, *Penicillium citrinum* and *Rhizopus stolonifer* from cocoyam cormels (Harter, 1916; D'Souza and Moniz, 1968; Coursey and Booth, 1972; Gollifer and Booth, 1973b; Ogundana, 1976; Maduewesi and Onyike, 1980; Okeke, 1980; Ogali, 1994). Even though Ampomah (1997) reported *Aspergillus* sp., he did not establish its species. This work is the first to implicate *Aspergillus flavus* in the storage rots of cocoyam. Certain strains of *Aspergillus flavus* have been reported to produce



aflatoxins that are harmful to humans (Samson and van Reenen-Hoekstra, 1988). The occurrence of *A. flavus* in this study, therefore, requires that further work be carried out to establish its aflatoxin-producing status.

The most frequently occurring pathogens causing post-harvest decay in cocoyam are those belonging to the genus *Fusarium*. Together they constitute 77.2% of the total isolations made from both the markets and the storage barn. *Botryodiplodia theobromae* and *Penicillium citrinum* were important as far as isolations made from market samples were concerned. The differential frequencies of occurrence of pathogens may be a reflection of their relative abundance in the soils of the locations where the cocoyam samples were produced and also the atmosphere in the markets and the barn where cormels were stored.

The problem of post-harvest losses has been identified as a major constraint to the production of root and tuber crops (Coursey and Booth, 1972; Booth, 1973; NAS, 1978; Ogali, 1994). Bikomot and Brecht (1989) reported that losses in cocoyam after harvest manifest in cormel weight loss, sprouting and decay. These interact to affect the quantity and quality of the stored product.

Of the factors affecting the quality of cocoyams in storage, however, losses caused by micro-organisms are by far the most serious (Booth, 1974). The occurrence of rots in the three varieties of cocoyam generally follows similar trends (Baybay, 1922; Praquin and Michel, 1971; Ogali, 1994).

The Amankanipa variety recorded a significantly lower incidence of rots than both the Amankanifitaa and Amankani Serwa varieties during the first fifteen weeks of storage. Interestingly, the Amankanipa variety also recorded a



consistently higher percent cormel weight loss than the other two varieties. The rate of dehydration in cocoyam cormels has been correlated to mycelial growth and pathogenesis of fungi (Coursey and Booth, 1972). With increased desiccation of the cormel, the inner flesh hardens and checks pathogenic entry, since pathogens generally prefer more succulent tissues (Arene and Okpala, 1980). It follows that where percent weight loss as a result of moisture content reduction was minimal, pathogenesis is high due to the ease of penetration by pathogens.

Incidence of rots in root and tuber crops has also been reported to be influenced by sprouting (NAS, 1978). Sprouting occurs after breaking of dormancy, a period during which satisfactory storage of the produce is no longer possible. It has also been reported that when sprouting occurs, over 50 percent rot is observed after two months and 95 percent after five months (NAS, 1978).

In this study, sprouting began in the Amankanifitaa and Amankani Serwa varieties during the first and fourth weeks after storage respectively whereas incidence of rots began in the second week in these varieties. This observation supports reported correlation between sprouting and incidence of rots. In the Amankanipa variety, however, even though sprouting did not occur until the 13th week after storage, incidence of rots began in the third week. It may be plausible to infer that even though dormancy was broken as late as the 13th week, the presence of the 'natural' wounds served as infection courts for rot-inducing pathogens, since in this variety of cocoyam 92.2% of rots originated from the breaking point.



The study showed that storage rots in cocoyam originate mostly from the proximal ends of cormels (Table 8). This is because of the wound created as a result of their detachment from the mother corm during harvesting. This gives credence to the belief that most of the rot pathogens are essentially wound parasites. Previous workers (Harter, 1916; Gollifer and Booth, 1973a; Ogundana, 1976; Maduwesi and Onyike, 1980) arrived at similar conclusions based on observations made on storage rots of cocoyam. In their study, Maduwesi and Onyike (1980) reported that of 1652 cases of rot which were observed at the early stages of decay, 62.2% originated from the proximal ends, 30.2% from lateral sides and 4.9% from the distal ends of cormels.

With this observation, it could be inferred that starting with sound, unbruised cormels the 'natural' wounds at the proximal ends of cormels become the obvious infection courts for pathogens. It follows therefore that rots in cocoyam could be reduced considerably if chemical treatments are targeted at the proximal ends of cormels instead of the entire surface of the cormel.

The fact that no rot was recorded as having originated from the distal ends of cormels may be the result of the intense cellular activity at this site due to the presence of the terminal bud. This provides an added endogenous factor for checking rots in cocoyam.

The effectiveness of thiabendazole as a post-harvest fungicide is well known. (Burden, 1969; Booth, 1974; Thompson *et al.*, 1977). The post-harvest application of lime on yam has also been reported (Kinman, 1921; Thompson *et al.*, 1977; Ogali, 1991; Cornelius, 1998). In this study, both thiabendazole and lime were

effective in inhibiting *in vitro* mycelial growth of most of the isolates as well as in controlling rots of cocoyam in storage.

Significant differences ( $P=0.05$ ) were observed in the efficacy of thiabendazole compared to lime in controlling rot size for the first six weeks of storage. Thereafter, no significant differences were observed even though the performance of thiabendazole was still better. Eckert and Kolbenzen (1964) and Scott and Roberts (1967) have reported that thiabendazole at a concentration as low as 140 ppm has been shown to be effective against black end in bananas. They further reported that thiabendazole at 1000 ppm also gave good control and greatly reduced storage losses in yam tubers in cold storage.

The effectiveness of lime in reducing rot size in stored cocoyam is probably the result of the alkaline nature of this material. Fungal mycelium generally prefer acidic medium with pH range of 4.0 - 6.4. The lime paste (pH = 12.40) is likely to have raised the pH of the treated surface considerably to alkaline levels to discourage fungal growth and reproduction. It may also have created a physico-chemical barrier against entry by rot-causing pathogens.

Coursey and Booth (1972) have reported that for successful post-harvest treatment, the germicide must have the property of reaching the pathogen after it has been deposited upon the surface of the host produce and that while many chemicals may show high *in vitro* activity against individual or groups of pathogens they do not always penetrate the host tissue sufficiently to give adequate disease control. This fact may account for differences in the performance of the

two test chemicals used in this study. Whereas thiabendazole is a systemic fungicide, lime, on the other hand, has protectant activity.

Thompson *et al.* (1977) expressed misgivings about the practice of coating yam tubers with lime to control storage rots since it renders the tubers unattractive and unsuitable for marketing. They also encountered traces of fungicide residues in tubers treated with thiabendazole fourteen days after application. Perhaps, the method of treating only the proximal end of cocoyam with would help minimise these problems in cocoyam.

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## APPENDICES

## APPENDIX 1

SURVEY ON POSTHARVEST HANDLING AND DETERIORATION OF  
COCOYAM IN GHANAQUESTIONNAIRE FOR COCOYAM SELLERS

Name.....

Location..... Date.....

Enumerator.....

Sex:            Male                    [ 1 ]                    Female                    [ 2 ]

**A.    TYPES OF COCOYAM AVAILABLE TO SELLERS**

- A1. For how long have you been selling cocoyam?  
 Under 5 years            [ 1 ]            Between 5 and 10 years            [ 2 ]  
 Between 10 and 15 years            [ 3 ]            Between 15 and 20 years  
 [ 4 ]            Over 20 years            [ 5 ]
- A2. What are the types of cocoyam you know of?  
 Pink [ 1 ]            White            [ 2 ]            Both            [ 3 ]  
 Other (specify.....)            [ 4 ]
- A3. Which of these types do you sell?  
 Pink [ 1 ]            White            [ 2 ]            Both            [ 3 ]            Other  
 (specify.....)            [ 4 ]
- A4. Why?.....  
 .....
- A5. Which of these types do consumers prefer most?  
 Pink            [ 1 ]            White            [ 2 ]  
 Other (specify.....)            [ 3 ]
- A6. Why?.....  
 .....

## B. SOURCE OF COCOYAM TO SELLERS

B1. Where do you obtain your cocoyam for sale?

Personal farm [ 1 ] Farm gate [ 2 ]  
 Village market [ 3 ] Through middlemen [ 4 ]  
 Other (specify.....) [ 5 ]

B2. Which area in Ghana do you obtain your cocoyam?

Adawso [ 1 ] Koforidua [ 2 ] Agogo [ 3 ]  
 Begoro [ 4 ] Tepa [ 5 ] Others  
 (specify.....) [ 6 ]

B3. What quantity of cocoyam do you buy per week?

Half sack [ 1 ] One sack [ 2 ] Two sacks  
 [ 3 ] Three sacks [ 4 ] Four sacks [ 5 ] Over  
 four sacks [ 6 ]

B4. Why?.....

.....

## C. HARVESTING, HANDLING AND TRANSPORTATION

C1. When is the peak period for harvesting cocoyam in Ghana?

Oct - Nov. [ 1 ] Dec. - Jan. [ 2 ] Feb. - Mar.  
 [ 3 ]  
 Apr. - May [ 4 ] Jun. and beyond [ 5 ]

C2. What is the time interval between harvesting and transportation?

Within a day [ 1 ] Two days [ 2 ]  
 Three days [ 3 ] Over four days [ 4 ]

C3. Before transportation, how do you store the cocoyam?

Spreading on the floor [ 1 ] In a basket [ 2 ]  
 In a sack [ 3 ] Other (specify.....) [ 4 ]

C4. What is the mode of transportation?

By road [ 1 ] By rail [ 2 ]

Other (specify.....) [ 3 ]

C5. In what way do you transport the cocoyam?

In sacks [ 1 ] In baskets [ 2 ]

Other (specify.....) [ 3 ]

C6. For how long does it take to transport the cocoyam from the farm/village to the market?

Within a day [ 1 ] In 2 days [ 2 ] In 3 days [ 3 ]

Over 3 days [ 4 ]

#### D. COCOYAM STORAGE

D1. Do you store your cocoyam? Yes [ 1 ] No [ 2 ]

D2. If yes, where do you store the cocoyam?

On the market [ 1 ] At home [ 2 ] Other

(specify.....) [ 3 ]

D3. How do you store the cocoyam?

In sacks [ 1 ] In baskets [ 2 ] In pits [ 3 ]

On the floor [ 4 ] On platforms [ 5 ] Other

(specify.....) [ 6 ]

D4. For how long do you store your cocoyam?

Under one week [ 1 ] One week [ 2 ] Two weeks [ 3 ]

Three weeks [ 4 ] Four weeks [ 5 ] Over four weeks

[ 6 ]

#### E. COCOYAM STORAGE PROBLEMS

E1. Do you experience storage problems in cocoyam?

Yes [ 1 ] No [ 2 ]

E2. Out of the quantity of cocoyam you buy per week, what percentage goes bad in storage?

0 - 5% [ 1 ] 6 - 10% [ 2 ] 10 - 20% [ 3 ]

21 - 30% [ 4 ] Over 30% [ 4 ]

E3. Do you encounter rotting in storage? Yes [ 1 ] No

[ 2 ]

E4. If yes, which type rots more easily? Pink [ 1 ]  
 White [ 2 ] Both [ 3 ] Not sure [ 4 ]

E5. Do you encounter sprouting in storage? Yes [ 1 ]  
 No [ 2 ]

E6. If yes, which type of cocoyam sprouts more easily?

Pink [ 1 ] White [ 2 ]  
 Both [ 3 ] Not sure [ 4 ]

E7. Do you encounter cocoyam dehydration in storage? Yes  
 [ 1 ] No [ 2 ]

E8. If yes, which type dehydrates more easily?

Pink [ 1 ] White [ 2 ]  
 Both [ 3 ]  
 Not sure [ 4 ]

E9. Any other storage problem?  
 (specify).....

.....

## F. CONTROL OF STORAGE PROBLEMS

F1. Do you make any effort to control storage problems? Yes  
 [ 1 ] No [ 2 ]

F2. If yes, how do you control these problems?

Applying wood-ash [ 1 ] Applying lime [ 2 ]  
 Any synthetic chemical [ 3 ] Applying cooking oil [ 4 ]  
 Curing [ 5 ] Sprinkling of water [ 6 ]  
 Other (specify.....) [ 7 ]





D7. If yes, which type of cocoyam sprouts more easily?

Pink	[ 1 ]	White	[ 2 ]
Both	[ 3 ]	Not sure	[ 4 ]

D8. Do you encounter cocoyam dehydration in storage? Yes [ 1 ] No [ 2 ]

D9. If yes, which type dehydrates more easily?

Pink	[ 1 ]	White	[ 2 ]
Both	[ 3 ]		
Not sure	[ 4 ]		

D10. Any other storage problem? (specify)

.....  
 .....

#### F. CONTROL OF STORAGE PROBLEMS

F1. Do you make any effort to control storage problems? Yes [ 1 ] No [ 2 ]

F2. If yes, how do you control these problems?

Applying wood-ash	[ 1 ]	Applying lime	[ 2 ]
Any synthetic chemical	[ 3 ]	Applying cooking oil	
[ 4 ] Curing	[ 5 ]	Sprinkling of water	[ 6 ]
Other (specify.....)		[ 7 ]	

## APPENDIX 3

Percent weekly mean weight loss of cormels of three cocoyam varieties (Amankanipa, Amankanifitaa and Amankani Serwa) stored over a sixteen-week period.

Variety	Duration of storage (week)							
	1	2	3	4	5	6	7	8
Amankanipa	3.82a	7.67a	9.83	11.66	13.29	14.33	15.10	15.44
Amankanifita	3.11b	6.94b	9.13	11.17	12.85	13.92	14.42	15.14
Amankani								
Serwa	3.29b	6.51b	8.36	10.61	12.48	13.24	14.16	15.08

Variety	Duration of storage (week)							
	9	10	11	12	13	14	15	16
Amankanipa	16.05	16.83	17.55	18.01	18.79	19.34	20.34	21.27
Amankanifitaa	15.94	16.59	17.55	18.13	18.62	19.14	19.74	20.28
Amankani								
Serwa	15.89	16.74	18.00	18.53	19.33	19.93	20.50	20.91

Means in a column followed by the same letter are not significantly different at  $p=0.05$ .

## APPENDIX 4

Analysis of variance (ANOVA) for percent cormel weight loss in three cocoyam varieties (Amankanipa, Amankanifitaa and Amankani Serwa) in storage.

First week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	0.033	0.011	0.7473	
Variety	2	1.078	0.539	36.8920	0.0004
Error	6	0.088	0.015		
Total	11	1.198			

Second week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	0.153	0.051	0.3724	
Variety	2	2.732	1.366	9.9937	0.0123
Error	6	0.820	0.137		
Total	11	3.705			

## APPENDIX 5

Percent mean weekly cormel sprouts of three cocoyam varieties (Amankanipa, Amankanifitaa and Amankani Serwa) over a sixteen-week period.

Variety	Duration of storage (week)							
	1	2	3	4	5	6	7	8
Amankanipa	0.0	0.0	0.0	0.0a	0.0a	0.0a	0.0a	0.0a
Amankanifitaa	1.25	1.25	1.25	11.25b	12.5b	12.5b	12.5b	15.0b
Amankani								
Serwa	0.0	0.0	0.0	8.75b	8.75b	8.75b	8.75b	10.0b

Variety	Duration of storage (week)							
	9	10	11	12	13	14	15	16
Amankanipa	0.0a	0.0a	0.0a	0.0a	1.25a	1.25a	1.25a	1.25a
Amankanifitaa	17.5b	17.5b	17.5b	17.5b	17.5b	17.5b	17.5b	17.5b
Amankani								
Serwa	12.5b	12.5b	12.5b	12.5b	12.5b	12.5b	12.5b	12.5b

Means in a column followed by the same letter are not significantly different at  $p=0.05$ .

## APPENDIX 6

Analysis of variance (ANOVA) for cornel sprouts of three cocoyam varieties (Amankanipa, Amankanifitaa and Amankani Serwa) in storage. (Data was angular-transformed before analysis).

Fourth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	43.74	14.58	0.47	
Variety	2	403.85	201.93	6.56	0.031
Error	6	184.76	30.79		
Total	11	632.35			

Fifth, sixth and seventh weeks

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	35.79	11.93	0.49	
Variety	2	469.07	234.54	9.64	0.013
Error	6	145.92	24.32		
Total	11	650.78			

Eighth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	33.19	11.06	0.63	
Variety	2	600.04	300.02	17.10	0.003
Error	6	105.28	17.55		
Total	11	738.51			

Ninth, tenth, eleventh and twelfth weeks

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	19.78	6.59	0.54	
Variety	2	781.09	390.54	31.87	<0.001
Error	6	73.52	12.25		
Total	11	874.39			

Thirteenth, fourteenth, fifteenth and sixteenth weeks

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	14.30	4.77	0.24	
Variety	2	628.95	314.48	16.04	0.004
Error	6	117.67	19.61		
Total	11	760.92			

## APPENDIX 7

Percent weekly mean incidence of cormel rots of three varieties of cocoyam (Amankanipa, Amankanifitaa and Amankani Serwa) over a sixteen-week period.

Variety	Duration of storage (week)							
	1	2	3	4	5	6	7	8
Amankanipa	0.0	0.0	2.5a	5.0a	7.5a	22.5a	41.3a	46.3a
Amankanifitaa	0.0	5.0	16.3b	31.3b	47.5b	55.0b	70.0b	75.0b
Amankani Serwa	0.0	2.5	8.75b	13.8a	26.3c	37.5ab	52.5a	58.8c

Variety	Duration of storage (week)							
	9	10	11	12	13	14	15	16
Amankanipa	50.0a	56.3a	62.5a	62.5a	65.0a	71.3a	71.3a	76.3a
Amankanifita a	77.5b	81.3b	82.5b	85.0b	85.0b	87.5b	87.5b	90.0b
Amankani Serwa	62.5a	67.5a	68.8a	71.3a	72.5a	73.8a	73.8a	75.0a

Means in a column followed by the same letter are not significantly different at  $p=0.05$ .

## APPENDIX 8

Analysis of variance (ANOVA) for incidence of cormel rots of three cocoyam varieties (Amankanipa, Amankanifitaa and Amankani Serwa) in storage. (Data was angular-transformed before analysis).

## Third week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	35.88	11.96	0.67	
Variety	2	402.80	201.40	11.25	0.009
Error	6	107.41	17.90		
Total	11	546.08			

## Fourth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	28.96	9.65	0.25	
Variety	2	931.65	465.82	11.88	0.008
Error	6	235.26	39.21		
Total	11	1195.87			

## Fifth week

Source	Degree of Freedom	Sum of Squares	Mean Square	F-value	Prob.
Replication	3	41.24	13.75	0.26	
Variety	2	1632.35	816.17	15.46	0.004
Error	6	316.66	52.78		
Total	11	1990.25			

## Sixth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	57.69	19.23	0.46	
Variety	2	806.65	403.33	9.63	0.013
Error	6	251.34	41.89		
Total	11	1115.69			

## Seventh week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	75.56	25.19	0.75	
Variety	2	588.74	294.37	8.72	0.017
Error	6	202.57	33.76		
Total	11	866.87			

## Eighth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	68.87	22.96	0.89	
Variety	2	756.40	378.20	14.63	0.005
Error	6	155.06	25.84		
Total	11	980.34			

## Ninth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	19.80	6.60	0.34	
Variety	2	571.48	285.74	14.78	0.005
Error	6	115.97	19.33		
Total	11	707.25			

## Tenth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	11.93	3.98	0.19	
Variety	2	515.79	257.89	12.20	0.008
Error	6	126.86	21.14		
Total	11	654.57			

## Eleventh week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	83.14	27.71	1.16	
Variety	2	401.02	200.51	8.42	0.018
Error	6	142.93	23.82		
Total	11	627.09			

## Twelfth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	33	66.34	22.11	1.18	
Variety	2	496.65	248.33	13.23	0.006
Error	6	112.65	18.77		
Total	11	675.64			

## Thirteenth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	69.28	23.09	1.65	
Variety	2	408.88	204.44	14.64	0.005
Error	6	83.81	13.97		
Total	11	561.97			

## Fourteenth and Fifteenth weeks

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	52.345	17.448	2.89	
Variety	2	344.605	172.302	28.58	<0.001
Error	6	36.173	6.029		
Total	11	433.124			

## Sixteenth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	77.988	25.996	3.03	
Variety	2	344.103	172.052	20.09	0.002
Error	6	51.396	8.566		
Total	11	473.487			

## APPENDIX 9

Analysis of variance for percent origin of rots in Amankanipa, Amankanifitaa and Amankani Serwa varieties after a sixteen week storage period. (Data was angular-transformed before analysis).

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	0.00	0.00	0.00	
Variety	2	0.00	0.00	0.00	1.000
Origin	2	30416.98	15208.49	717.54	0.001
Variety*Origi	4	175.50	43.88	2.07	0.116
n					
Error	24	508.69	21.20		
Total	35	31101.17			

## APPENDIX 10

Diametric growth (mm) of fungal isolates on PDA amended with three levels each of thiabendazole and lime at seven days after incubation

Isolate	Thiabendazole (ppm)				Lime (g/litre)			
	0	250	500	1000	0	50	100	200
<i>Aspergillus flavus</i>	66.3	0.0	0.0	0.0	75.9	25.7	10.2	0.0
<i>Botryodiplodia theobromae</i>	90.0	0.0	0.0	0.0	90.0	0.0	0.0	0.0
<i>Fusarium oxysporum</i>	47.3	0.0	0.0	0.0	77.0	35.7	0.0	0.0
<i>Fusarium solani</i>	54.5	0.0	0.0	0.0	70.0	59.3	0.0	0.0
<i>Penicillium citrinum</i>	33.0	15.5	14.5	14.2	42.3	23.3	0.0	0.0
<i>Rhizopus stolonifer</i>	90.0	90.0	90.0	90.0	90.0	90.0	20.7	0.0

Note: Isolates were cultured in 90 mm diameter petri dishes.

## APPENDIX 11

Mean rot size ( $\text{mm}^2$ ) of Amankanipa variety of cocoyam treated with thiabendazole and lime and stored over a ten-week period

Treatment	Duration of storage (week)				
	2	4	6	8	10
Control	25.0a	46.7a	121.0a	150.1a	274.9a
Thiabendazol	6.7b	20.1b	21.3b	69.1b	121.6b
e					
Lime	23.2a	30.6c	73.3c	98.6b	160.2b

Means in a column followed by the same letter are not significantly different at  $p=0.05$ .

## APPENDIX 12

Analysis of variance (ANOVA) for mean rot size (mm<sup>2</sup>) of Amankanipa variety of cocoyam treated with thiabendazole and lime during storage

## Second week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	14.76	4.92	0.36	
Treatment	2	684.51	342.25	25.39	0.001
Error	6	80.88	13.48		
Total	11	780.15			

## Fourth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	108.12	36.04	1.59	
Treatment	2	1430.34	715.17	31.49	<0.001
Error	6	136.27	22.71		
Total	11	1674.73			

## Sixth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	691.40	230.50	1.75	
Treatment	2	19892.50	9946.30	75.53	<0.001
Error	6	790.20	131.70		
Total	11	21374.10			

## APPENDIX 12

Analysis of variance (ANOVA) for mean rot size (mm<sup>2</sup>) of Amankanipa variety of cocoyam treated with thiabendazole and lime during storage

## Second week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	14.76	4.92	0.36	
Treatment	2	684.51	342.25	25.39	0.001
Error	6	80.88	13.48		
Total	11	780.15			

## Fourth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	108.12	36.04	1.59	
Treatment	2	1430.34	715.17	31.49	<0.001
Error	6	136.27	22.71		
Total	11	1674.73			

## Sixth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	691.40	230.50	1.75	
Treatment	2	19892.50	9946.30	75.53	<0.001
Error	6	790.20	131.70		
Total	11	21374.10			

## Eighth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	454.70	151.60	0.24	
Treatment	2	13444.70	6722.30	10.76	0.010
Error	6	3749.90	625.00		
Total	11	17649.20			

## Tenth week

Source	Degree of Freedom	Sum of Squares	Mean Squares	F-value	Prob.
Replication	3	831.00	277.00	0.24	
Treatment	2	50880.00	25440.00	22.08	0.002
Error	6	6913.00	1152.00		
Total	11	58625.00			